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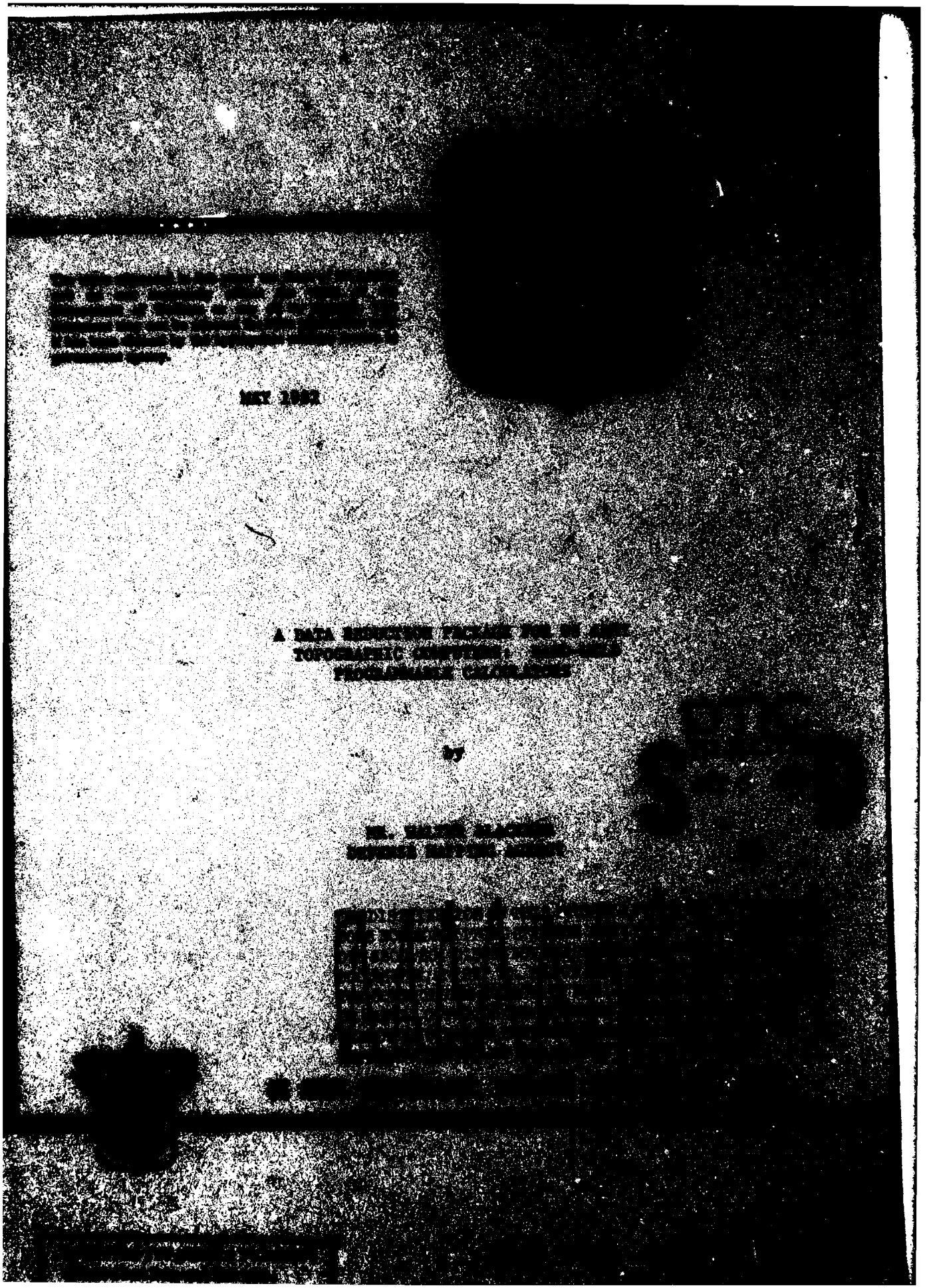

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This study was done to provide the US Army with the basis for a standardized program package for use with hand-held, programmable calculators. The programs are written and published in a format which is immediately useable with the Texas Instruments Programmable 59 Calculator, but which can easily be adapted for use with other programmable calculators. Other Department of Defense agencies may also find them valuable in training and operational efforts. The study includes a general overview of the history of the Topographical Engineers

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US ARMY WAR COLLEGE

MILITARY STUDIES PROGRAM PAPER

A DATA REDUCTION PACKAGE FOR US ARMY TOPOGRAPHIC COMPUTERS: HAND-HELD PROGRAMMABLE CALCULATORS

BY

MR. WALTER BLACKMER
DEFENSE MAPPING AGENCY

25 MAY 1982

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ABSTRACT

AUTHOR: Mr. Walter Blackmer, Defense Mapping Agency

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CHAPTER I

INTRODUCTION

The US Army and other Department of Defense agencies have in their inventories several types of hand-held, programmable calculators, particularly the Texas Instruments 59 (TI-59). There exists no package of standardized programs for use in the reduction of topographic data. Each using agency has put together a few programs which are of local import.

Discussions were held with personnel of the 171st Engineer Detachment (TOPO) (INTEL) which is part of the US Army Forces Command at Fort McPherson, Georgia and with staff members at the Defense Mapping School (DMS) located at Fort Belvoir, Virginia. These discussions indicate a need for a standardized package of data reduction programs which can be used in the instruction of students of topographic computing and by the operational topographic computer in the field. Most topographic computers are assigned to units engaged in the collection of survey data in support of larger units. They do not have access to immediate data processing equipment to provide the near-real-time data reduction which is required by field units. The use of pre-programmed data reduction which provides consistent and error-free arithmetic calculations on input data can prevent costly delays and mistakes.

The data processing package currently available (Texas Instruments Programmable 59 Calculator with a Surveying Module = $188; Print/Security Cradle, PC 188 Series = $158) is inexpensive enough to be readily available in quantity for all units and, in reality, this equipment could be part of the accountable, but expendable inventory.

CHAPTER II

HISTORICAL VIEW OF TOPOGRAPHICAL ENGINEERS

A complete history of the Topographical Engineers in the US Army would be a very large volume. This study makes no attempt at completeness; it is an essay that tries to capture and communicate some of the atmosphere surrounding the evolution of the Topographical Engineers from their beginnings in the Revolutionary War to its present mission and status. The reader is directed to the many selected references for an extensive and detailed history and an expanding bibliography on the subject.

I was a member of several topographic units located in the United States, Pacific Theater, and Europe during the years 1949 through 1958. These units exhibited the highest degree of professionalism at all times and truly justified a reference to the Corps of Engineers in a letter, dated 5 September 1953, from Major General Julian L. Schley to the Historical Division.

> Insisting on the correct nomenclature, old Colonel E.E. Winslow used to remind young officers that the difference between 'Engineer Corps' and 'Corps of Engineers' was the same as the difference between a 'beer bottle' and a 'bottle of beer'.

The first Topographical Engineer in the history of the United States was Robert Erskine of New Jersey who was appointed Geographer and Surveyor in the Continental Army by General George Washington on 25

July 1777. He was assigned the task of making sketches of the country. He was succeeded upon his death by Simeon De Witt who had been his assistant. Thomas Hutchins was also appointed in the same capacity as a "Geographer of the United States of America." In the postwar years there was little use for topographers and they became land surveyors and geographers. The most significant fact was that these men represented a branch of engineering which was different from that previously known. They were set apart from the usual military engineer. (Geotzmann, 1959).

The first official recognition and appointment of Topographical Engineers for which I found a record happened during the War of 1812 as an act of Congress approved on 3 March 1813. Pertinent regulations prescribed their duties as essentially mappers involved in making plans of military positions, making reconnaissance sketches and notes for intelligence purposes, and exhibiting the positions of contending armies on the fields of battle (Goetzmann 1959 and Beers 1942).

The Topographical Engineers were disbanded in 1815 simply because no provision had been made in the Congressional Act for their retention. Two topographic officers had been retained under other authority and were assigned to complete the surveys on the northern frontier and Lake Champlain. To fulfill the need for frontier military surveys a corps of topographical engineers was established by law under the direction of the Chief of Engineers on 24 April 1816. They operated for more than twenty years until the Army Reorganization Act of 5 July 1838 raised their status to a Corps of Topographical Engineers at last equal to the regular Corps of Engineers and subject only to the control of the Secretary of War (Goetzmann, 1959).

During the period between 1816 and 1838 the Topographical Engineers

had been involved in harbor surveys, plans for roads and canals, frontier surveys, and many other types of surveys in all parts of the United States. So numerous were the demands upon their services, that it was impossible to fill all of the requests. Beginning in 1834 the Topographical Engineers were employed in connection with the construction of lighthouses. In 1836 several Topographical Engineers were transferred to Florida for service with the Army against the Seminole Indians (Beers 1942).

The United States Military Academy which was established in 1802 remained as the only school of civil engineering in the United States until the 1830s. An early graduate of West Point, Colonel John James Abert, who was regarded as one of the leading geographers of his time, was the director of the Corps of Topographical Engineers from its inception in 1838 through practically the entire span of its life (1838 to 1863, when it was merged with the Corps of Engineers) (Davis 1967). During that period seventy-two officers served in the corps. Sixty-four of them were graduates of West Point. The topographical officer during the twenty years preceding the Civil War was commonly a polished gentleman and a sophisticated intellectual. This group of men which comprised the Corps of Topographical Engineers was an important part of the exploration of the west. They were required to act as soldier, diplomat, scientist, geographer, geologist, surveyor, mapper, computer, etc. while travelling by foot, horseback, and wagon. They were sent to areas of recognized combat such as during the Mexican War. They helped make this country great and even though the corps was short-lived, their achievements remain as a monument to their dedication and competence (Goetzmann 1966). Some, but not nearly enough, peaks in the Rocky

Mountains bear their names in tribute to their contributions. I have always felt that if the landings on the moon had been accomplished in the Nineteenth Century, the geologist who set foot there would have been a member of the Topographical Engineers.

Many engineers in the US Army rose in rank during the Civil War (Beers 1942). Some statistics are in order to show how significant their contributions were. Of the forty-eight officers in the Corps of Engineers at the beginning of the war, two, Lee and Bureaugard, became full generals, eighteen became major generals, and twelve achieved the rank of brigadier-general. Of the forty-five officers in the Corps of Topographical Engineers, twelve became major generals and six became brigadier generals. The most remembered of these, of course, is Major General George Gordon Meade, who commanded the Army of the Potomac and defeated Lee at Gettysburg.

Not much is written specifically about the topographic engineers after their merger with the Corps of Engineers in 1863, but they must have been put to good use because there were surveys to be done and maps to be made. Many of the surveys had been taken over by the US Coast and Geodetic Survey in the Department of Commerce. There was a company (E) of the Old Battalion of Engineers which was officially designated as a topographical company and served in Cuba during the Spanish American War of 1898 (Davis 1957). West Point continued its tradition of sending only the highest ranking cadets to the Corps of Engineers. A young cadet by the name of Douglas A. MacArthur came to the Corps in 1903.

The Old Battalion passed away in 1901 as Congress authorized three battalions of engineers consisting of four companies each. These engineers performed admirably around the world, notably in the Philippines, but the greatest feat of the era remained to be accomplished by an Army

Engineers colonel, George Washington Goethals, (USMA Class of 1880) who saw to the completion of the Panama Canal where others had failed before.

The topographic engineers surface again as a distinct and sizeable unit on 18 May 1917 in the National Army of the United States as the 29th Engineer Regiment. A unit was so designated at Ft. Devens, Massachusetts on 28 October 1917. The 29th Engineers, Company H, was among the first arrivals in France with General Pershing during World War I. The 29th never functioned as a regiment, but supplied battalions and companies to various armies, corps, and divisions for surveying and map making. One battalion was used for flash and sound ranging for the field artillery. After the war ended the 29th Engineers was disbanded. On 4 July 1923 the 29th Engineer Battalion (Topographic) was activated from the deactivated 17th Engineer Battalion at Fort Humphreys (now Fort Belvoir), Virginia.

Their history was exciting to say the least with assignments to Nicaragua to survey for a possible new canal in 1929, relief work in Managua following the earthquake in 1931, production of topographic maps of New York City from 1931 to 1934, then on to the west coast for the next eight years mapping the Olympic Peninsula and Puget Sound areas of Washington State. Battalion headquarters was stabilized in Portland, Oregon in 1937 where the unit pioneered the development and use of aerial photogrammetric mapping.

War threatened in 1939 causing an immediate expansion of the 29th Engineer Topographic Battalion similar to that in World War I. The greatest wartime task completed by the 29th Engineers was the mapping of the Aleutian chain of islands, including Attu and Kiska. Many topo-

graphic units of platoon, company, and battalion size were activated to provide surveying and mapping products during World War II. Most were deactivated immediately following the cessation of hostilities in 1945.

The Post Hostilities Mapping Program was established in October 1945 and assigned to the 29th Engineer Topographic Battalion stationed first at Mandaluyong, Rizal on the outskirts of Manila, Philippine Islands and later at Cavite, Philippine Islands. The battalion had been shipped to the Philippines on 6 July 1945 to support the mapping requirements for the future operations in the Pacific Areas, principally the invasion of Japan. The Post Hostilities Mapping Program was successfully completed six years ahead of schedule in 1954. It was not an easy time for the 29th as twenty-two men lost their lives to headhunters, guerrillas, disease, and accidents during the nine year operation.

Other topographic units which were still active in the 1950s were the 64th BN in Tokyo which deactivated upon arrival of the 29th BN from the Philippine Islands, the 38th BN which eventually moved from the Presidio in California and is still active at Fort Belvoir, Virginia, and the 656th Engrs which supported the Engineer Intelligence Center located in Schwetzingen-Heidelberg, West Germany.

More recent history shows that topographic units were present and fulfilling their basic missions in the Korean and Vietnamese Wars. Technological advances in the art and science of data collection and reduction techniques for geodetic determinations have necessitated the reorganization of units, redefinition of missions, and a shift of responsibilities within the Department of Defense. Since 1972 when the Defense Mapping Agency was established, the Topographical Engineer component of the US Army has shifted its emphasis from map-making to the direct support of combat units.

At present there are 1,886 military topographic troops assigned to the US Army Forces Command. They are members of ten active units, eight reserve units, and one national guard unit. Their locations extend throughout the United States, Panama, and Europe with assignments to I Corps, III Corps, and the XVIII Airborne to mention just a few (See Figure II-1). Their equipment is modern and efficient and training takes place at Ft. Belvoir, Virginia. Presently, their mission is to provide terrain analyses, boundary surveys, establishment of supplemental survey control, and artillery surveys for ranges and firing exercises. As usual, the Topographical Engineers are at the forefront of the military posture of the United States because of their active participation in the Rapid Deployment Joint Task Force (RDJTF).

When it was decreed in 1863 that the Corps of Topographical Engineers would no longer be a separate branch of the US Army and that it was to be merged with the Corps of Engineers, the Military Academy was the main source of instruction for Army topographical officers and schools were established as needed to provide additional topographical training.

Until 1918 topographical officers received training at the School of Application at Willets Point, Long Island, New York. Map reproduction and lithographic schools were established and used during the period from 1918 to 1918 at Fort McNair, Washington, D.C. In 1918 during our involvement in World War I the School of Surveying, Map Reproduction, and Ranging opened at Fort Belvoir (known then as Camp A.A. Humphreys), Virginia to train the much needed officer and enlisted personnel in map making skills.

TOPOGRAPHIC SUPPORT UNITS - 1982

LISTING OF PRESENT TOPOGRAPHIC UNITS

DESIGNATION (See note 1)	MISSION (See note 2)	LOCATION
ACTIVE		
30th Engr BN	A, C, S, T	Ft. Belvoir, VA
63rd Engr CO	C, T	Ft. Bragg, NC
524th Engr CO	C, T	Ft. Hood, TX
531st Engr Det.	T	Ft. Ord, CA
537th Engr Det.	T	Ft. Lewis, WA
542nd Engr Det.	T	Ft. Stewart, GA
573rd Engr Det.	T	Ft. Riley, KS
588th Engr Det.	T	Ft. Carson, CO
714th Engr Det.	T	Ft. Polk, LA
917th Engr Det.	T	Ft. Campbell, KY
RESERVE		
302nd Engr CO	C	Corpus Christi, TX
334th Engr Det.	T	Nashville, TN
343rd Engr CO	S, T	New Kensington, PA
359th Engr Det.	T	San Diego, CA
601st Engr Plt.	MD	Atlanta, GA
624th Engr Plt.	MD	St. Louis, MO
663rd Engr CO	C	Long Beach, CA
759th Engr CO	MD	Annapolis, MD
NATIONAL GUARD		
1203rd Engr BN	A, C, S, T	Dothan, AL

Note 1: BN-Battalion; CO-Company; Det-Detachment; Plt-Platoon.

Note 2: A-Army; C-Cartographic; MD-Map Distribution; S-Survey; T-Terrain Analysis.

Figure II-1

On 1 July 1972 there was formed a new agency within the Department of Defense. This agency was named the Defense Mapping Agency and consisted of five components. One of these components is the Defense Mapping School (formerly the Department of Topography, an academic department of the US Army Engineer School) which is totally committed to producing highly trained and motivated personnel to carry on the long standing traditions initiated many, many years ago by now famous people who served as topographical engineer personnel.

CHAPTER III

A LOOK AT THE COMPUTATIONAL EARTH

General George Washington once said, "Impress on every man from the first to the lowest the importance of the cause and what it is they are contending for." That statement is the basis for including this chapter.

I can find no basic difference between topographic and geodetic computing. There may be some substance to statements about "geodetic" being "attuned to scientific research" and "topographic" being "surface or user oriented." I guess that I would probably agree to differences if I had not started my career as an Army Topographic Computer and since become a professional geodesist. There are also those who would have us believe that because topographic computing is used for survey projects requiring lesser accuracies than those needed in geodetic projects, time and effort will be wasted in upgrading topographic data reduction processes. This may have been true in the days of the "adding machine," but certainly not now with the availability of powerful, hand-held calculators which can be programmed and are capable of performing large iterative-type calculations in a very short time.

I feel that it is very important that anyone who is involved in topographic/geodetic computations have a basic understanding of what they are dealing with. Not only is this a great motivational factor,

but those who understand the basic fundamentals of the "mathematical surface" of the earth are capable of making contributions and improvements in the overall computational effort.

The programs which are provided in the appendices to this paper are considered to be geodetic data reductions. One can readily see that they are also applicable to topographic requirements. These programs will provide more accurate results than the standard computations used by the US Army. The reason for this increased accuracy is that the formulas and related forms formerly used were selected for "hand computations" using four function calculators (Friden, Marchant, etc.) or logarithm tables. These types of computations require closed formulas with two or three decimal accuracy in some of the terms. Calculators such as the Texas Instruments Programmable 59 use twelve significant digit accuracy routinely with amazing speed.

In order to easily perform computations of positions for the surface of the earth (geoid), we must adopt a mathematical surface which closely approximates the actual shape of the earth such as a sphere. The sphere is used in many geodetic problems which can then be solved with sufficient accuracy by well known methods of spherical trigonometry, but the shape of the earth is represented much better by an ellipse because of the flattening at the poles and the equatorial bulge. Figure III-1 (Geodesy for the Layman, 1959) shows the general ellipse used in computations. To achieve a three-dimensional figure: hold the PP' axis and rotate the major axis about it. The resultant ellipsoid in most cases will be very close to a sphere, but because "a" is larger than "b", it takes on somewhat of a short-pumpkin shape.

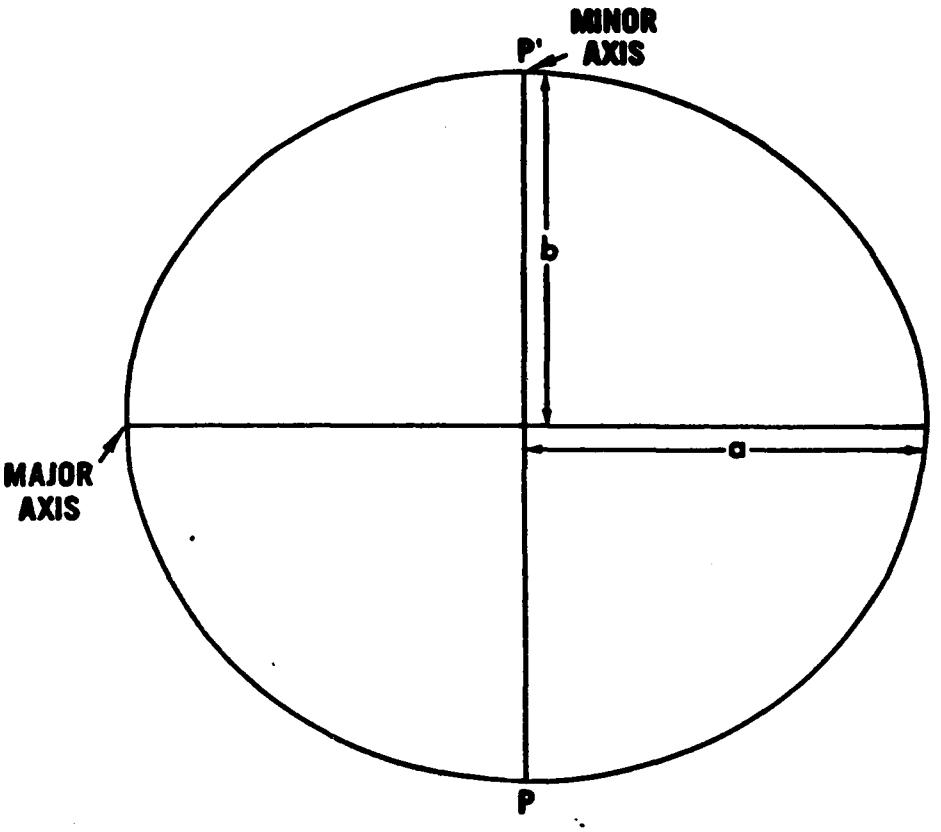
There are many ellipsoids in use throughout the world. Figure III-2 (Geodesy for the Layman, 1959) lists some examples which may be famil-

iar to some readers. The ultimate goal for the United States is to create and gain acceptance of a world geodetic system which is based on satellite data and will be useful to all. Figure III-3 (Geodesy for the Layman, 1959) shows shape relative to flattening.

Points on the earth can be defined in terms of geodetic coordinates based on ellipsoidal computations. These latitudes, longitudes, and elevations can be transformed to values on other ellipsoids or the actual earth (geoid) when sufficient relativity of the systems is known.

Figure III-4 (Basic Geodesy, 1977) shows the relationship of the three important surfaces that have been discussed.

ELEMENTS OF AN ELLIPSE



a = ONE-HALF OF THE MAJOR AXIS = SEMI-MAJOR AXIS

b = ONE-HALF OF THE MINOR AXIS = SEMI-MINOR AXIS

f = FLATTENING = $\frac{a - b}{a}$

PP' = AXIS OF REVOLUTION OF THE EARTH'S ELLIPSOID

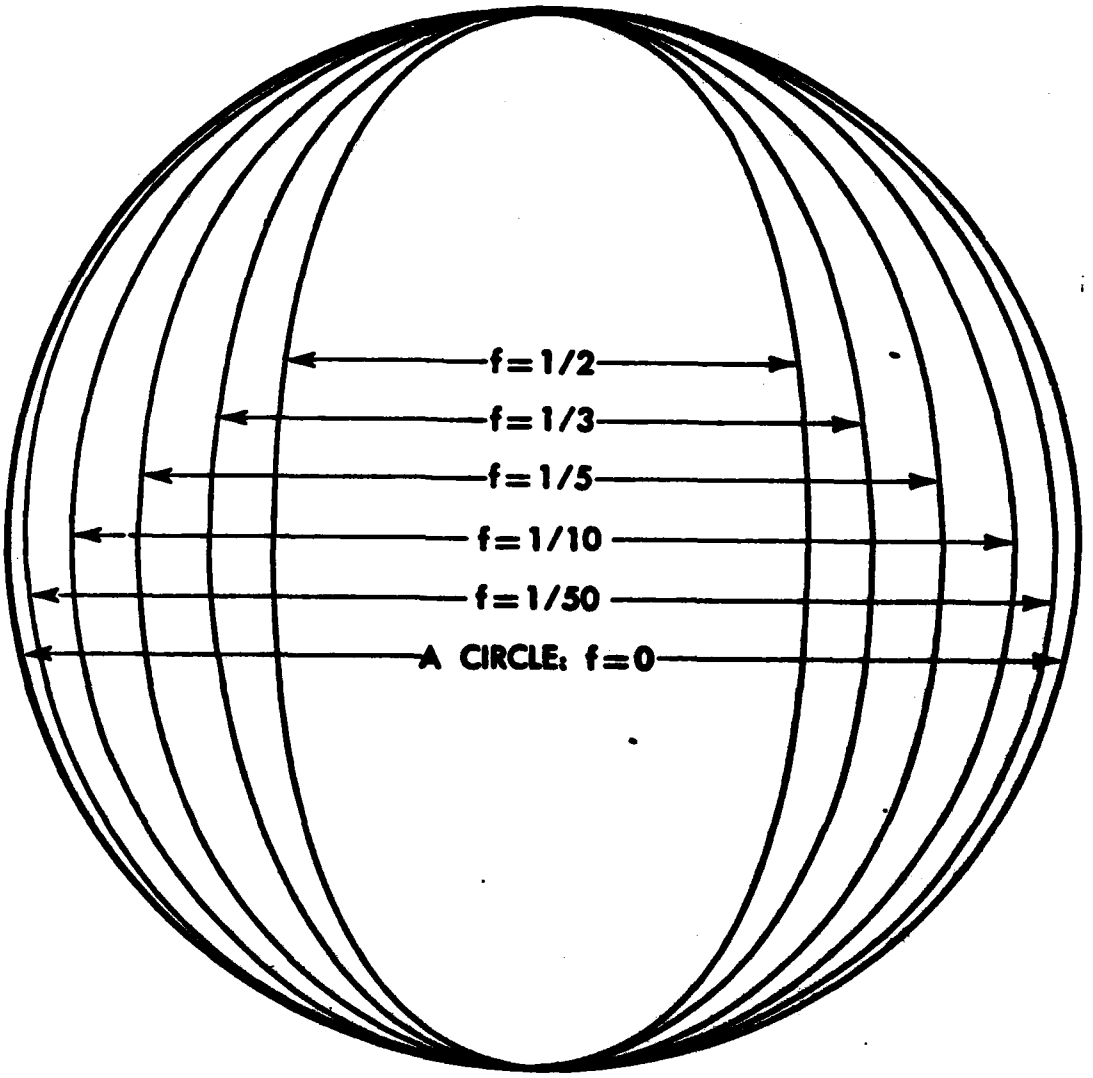
(From Geodesy for the Layman, 1959)
Figure III-1

SOME EXAMPLES OF REFERENCE ELLIPSOIDS

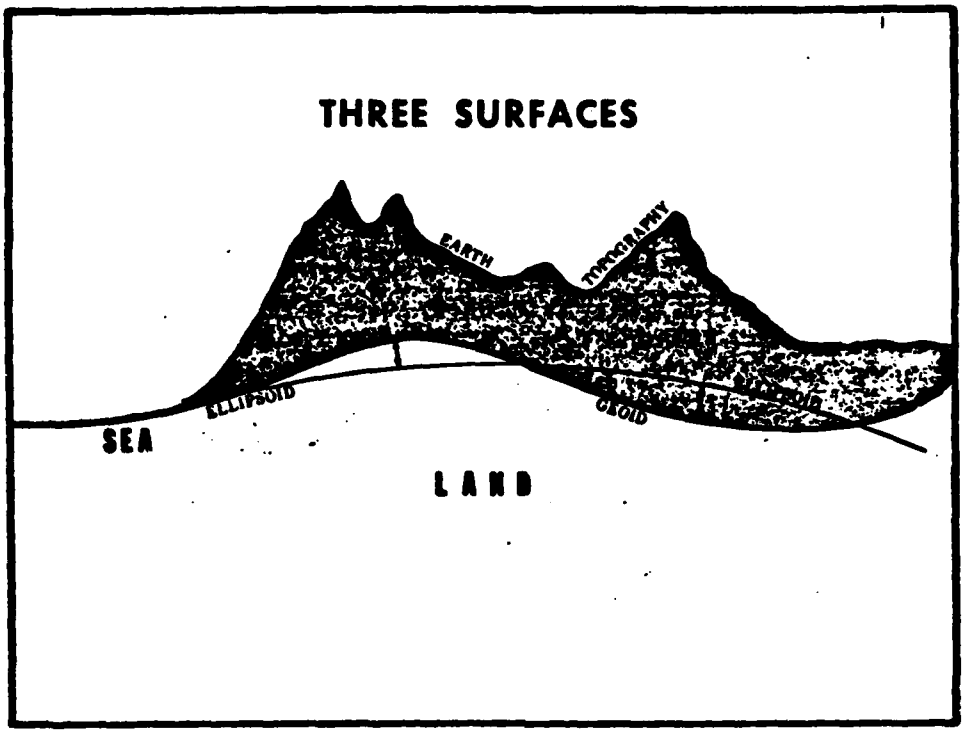
NAME	EQUATORIAL RADIUS	FLATTENING	WHERE USED
Hough (1956)	6,378,270	1/297	New AMS Solution
Krassowsky (1940)	6,378,245	1/298	Russian Datum
International (1924)	6,378,388	1/297	European Datum
Clarke (1866)	6,378,206	1/295	North American Datum
Clarke (1880)	6,378,249	1/293	New French, Africa
Everest (1830)	6,377,276	1/300	Indian Datums
Bessel (1841)	6,377,397	1/299	Tokyo Datum
Helmert (1907)	6,378,200	1/298	Egypt

Figure III-2

THE EARTH'S FLATTENING IS ABOUT 1/300



(From Geodesy for the Layman, 1959)
Figure III-3



Actually, things are quite complicated. When we talk about a pear-shape or an ellipsoid, we obviously do not mean the shape produced by the mountains and valleys, the topography. Since we can measure the elevations of places above sea level (this is what is recorded on topographic maps), we can discount them and inquire into the shape of what is left: that is, the sea-level surface itself, as if it were extended from the sea shore into the land areas without those elevations above it. This sea-level surface is also called the GEOID. The shape of the geoid is what we mean by the Figure of the Earth.

We have found from many measurements that the shape of this geoid is very irregular as compared with an ellipsoid, and we describe these irregularities by the distances from the much smoother ellipsoid. These distances are called GEOIDAL HEIGHTS.

Thus we distinguish three surfaces: the topography, the geoid, and the ellipsoid. Topographic maps give the elevations above sea level (the geoid). Geoidal maps give the geoidal heights in relation to the ellipsoid. Both together give the total height of the topography above the ellipsoid at any point.

(From Basic Geodesy, 1977)
Figure III-4

CHAPTER IV

GENERAL INFORMATION ABOUT THE PROGRAMMABLE CALCULATOR AND ASSOCIATED PRINTER

Today's hand-held calculators are the result of a long line of ingenious methods invented by man to make life's mathematical tasks easier. This is viewed in two ways: The "Type-A" individual sees the latest invention as an aid to his accomplishing more than ever by working extra hours while the "Type-B" perceives all labor-saving devices as a way to get his work done with less effort and to provide him with more leisure time. TO EACH HIS OWN.

We now have hand-held calculators available which have programmability and an optional printing capability. One of these is the Texas Instruments Programmable 59 (hereafter referred to as the "TI-59") with the optional Texas Instruments Print/Security Cradle, PC-100A (hereafter referred to as the "Printer") and is the subject of this discussion.

It is not my intention to provide complete descriptions of the equipment and its capabilities. I do wish to impart some general information and then refer you to the manuals which are provided with each programmable calculator and optional attachments. It is imperative that these manuals be read and studied and that their instructions for the use, care, and maintenance of the equipment are strictly adhered to in every instance. Taking the utmost care with electronic equipment will lead to longer equipment life and fewer maintenance problems along the

way.

I presume that each TI-59 calculator purchased by the US Army will include the procurement of the optional Printer. The calculators and printers pairings are interchangeable for operational use which will enhance "direct exchange" procedures in the supply channels. As I noted earlier in this study, initial unit cost is very inexpensive and care must be taken when maintenance versus replacement decisions are made. Repair estimates and minimum repair charges when coupled with handling and shipping costs, soon exceed replacement value. Down-time or the period of time when the unit is below minimum stock levels may make replacement of the item more attractive or necessary.

Texas Instruments Incorporated features pre-programmed modules containing programs which may be of interest to some users. Each calculator is sold with the Master Library module already inserted in the back and a Master Library Manual is also included.

One can now imagine the power of the TI-59 when considering that it can be used as a potent calculator for problems which do not require programs and storage, or with programs stored on magnetic cards, or with pre-recorded programs on modules. No matter how one chooses to employ the calculator there is also the option of using the Printer to provide a hard copy of all calculations for permanent records or for ease in checking the results.

The TI-59 can be operated by a battery pack which is rechargeable. The charger unit also allows the use of 110 Volt AC to power the calculator. When the calculator is attached to the Printer, there is the disadvantage of requiring 110 Volt AC for a power source. I have confidence that this problem will be overcome by Texas Instruments Incorpo-

rated because other manufacturers, e.g. Hewlett Packard Incorporated, have already done so.

I consider the Algebraic Operating System (AOS) used by Texas Instruments Incorporated in their calculator to be a distinct advantage to the using community. This is the more common method of entry for calculators used throughout the United States, precludes one more learning aspect for individuals, and is more compatible with the methods used in hand computations.

The calculator is equipped with controls over the Printer. Those input, output, or intermediate values for which hard copy is desired will be printed on command from within the program. The Printer can output both alpha messages and numeric values which can be quite useful in providing "prompts" for operator input or for labelling input, output, or intermediate data.

Note that there are convenient ways to program data reduction solutions in the TI-59 which will provide useful output to the user when the TI-59 is used alone or with the optional printer attached. The use of an output subroutine provides for the insertion or deletion of a critical "HALT" command in a single location to provide visual or hard copy output of data to the user.

This means that when the printer is attached and the "HALT" command is absent, data will be printed and calculations will continue uninterrupted until additional input by the user is required. It also means that when the calculator is detached from the printer and the "HALT" command is present, data will be displayed for recording by the user and calculations will continue only upon the "RUN" command.

All programs can be initialized by depressing the "A" key on the calculator. Exceptions to this rule should be allowed to an experienced

operator who does not require some parts of the program such as printed instructions to perform the calculations. Some operators may wish to drop parts of the provided programs, relabel subroutines, provide conditional transfers within the program, or reprogram the calculations to suit their operational purposes. Care must be taken that any modifications do not destroy the validity and/or consistency of the existing program.

Programming can be fun, exciting, and rewarding. I hope that this study effort will act as a stimulus to all potential users which will cause further studies and programming efforts in this area. Each appropriate level headquarters should determine their specific requirements and program needs which could then be modularized by the manufacturer. Cards can be used as the interim solution but should not be depended upon during periods of near-real-time requirements.

For information concerning the Texas Instruments hardware and software the following address and telephone numbers are provided:

Texas Instruments Incorporated
P.O. Box 53
Lubbock, Texas 79408

Toll-free (except Texas): 800-858-1802
(Texas): 800-692-1353

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APPENDIX A

SOLUTION OF GEODETIC TRIANGLES

Purpose: Reference TM 5-237, Surveying Computer's Manual, 1964. Page 133, Paragraph 57.

The basic computation in triangulation is the triangle solution. When two angles and one side are known, this case is known as an intersection problem with the third angle concluded from the other two angle observations. Normally, all three angles are observed. The solution of this problem is made by the law of sines (See the "FORMULATION and COMPUTATION" section which follows).

NOTES:

1. Given one side and either two or three observed angles of a triangle, this program solves for the amount of spherical excess, triangle misclosure, the two remaining sides (using plane angles), and the three spherical angles for use in the computation of geodetic positions.
2. This program is designed to be used with the TI Printer (PC-188 Series).

INSTRUCTIONS:

1. Printer "ON" and, then, Calculator "ON".
2. Load the four sides of the magnetic cards:
   a. CLR, RST, 1, 2nd, OP, 17, 1, INV, 2nd, WRITE; Enter Side 1.

b. 2; Enter Side 2.

c. 3; Enter Side 3.

d. 4; Enter Side 4.

Note: The numbers which are underlined may be replaced by zeroes. Refer to operating instruction manual if difficulty occurs.

3. Depress "A" for information and instructions.

FORMULATION and COMPUTATION:

1. Both Cases:

   a. Spherical Excess = $(a^2 * \sin 2 * \sin 3)/(393\ E06 * \sin 1)$

   b. The unknown sides are computed using the known side and plane angles through the Law of Sines.

   c. Plane angle equals (Spherical Angle - one-third Spherical Excess).

2. Case of a known side and three observed angles:

   a. Triangle Misclosure = (Sum of the Observed Angles) minus (180 degrees plus Spherical Excess).

   b. Spherical Angle = (Observed Angle) minus (one-third of the Triangle Misclosure).

3. Case of two Observed Angles and their included side (A common condition known as the intersection solution):

   a. Remaining (Concluded) Angle = 180 degrees minus (sum of the two Observed Angles plus the Computed Spherical Excess).

   b. Triangle Misclosure = Zero because this is a "Concluded Triangle."

INPUT DATA:

1. Side opposite angle no. 1, in meters

2. Angle 1.

   a. If observed, enter angle.

b. If not observed, enter zero.

3. Angle 2.

4. Angle 3.

SAMPLE RUNS

```
TRIANGLE COMPS
1 SIDE/ 2 OR 3  ANGS
FORMAT AS FOLLOWS:

ANG D.MS/LINEAR MTRS

INPUT DATA IN ORDER:

SIDE/ANG 1-2-3
IF CONCLUDED ANG 1=0


    32123.456
    90.000231
    60.000115
    30.000057

SPHER EXS:
         1.14     SECS

TRIANGLE CLOSES AT:
         2.89     SECS

COMP SIDE 1 TO 3 IS:
   27819.7139     MTRS

COMP SIDE 1 TO 2 IS:
   16061.6237     MTRS


SPHERICAL ANGLES ARE

    90.000135
    60.000019
    29.595960


THAT WAS AN EASY ONE
WANNA TRY ANOTHER ??

SIDE/ANG 1-2-3
IF CONCLUDED ANG 1=0
```

```
TRIANGLE COMPS
1 SIDE/ 2 OR 3  ANGS
FORMAT AS FOLLOWS:

ANG D.MS/LINEAR MTRS

INPUT DATA IN ORDER:

SIDE/ANG 1-2-3
IF CONCLUDED ANG 1=0


    32123.456
           0.
    60.000115
    30.000057


SPHER EXS:
         1.14     SECS

TRIANGLE CLOSES AT:
         0.00     SECS

COMP SIDE 1 TO 3 IS:
   27819.7890     MTRS

COMP SIDE 1 TO 2 IS:
   16061.7538     MTRS


SPHERICAL ANGLES ARE

    89.595942
    60.000115
    30.000057


THAT WAS AN EASY ONE
WANNA TRY ANOTHER ??

SIDE/ANG 1-2-3
IF CONCLUDED ANG 1=0
```

PROGRAM LISTING

```
000  22  INV
001  58  FIX
002  47  CMS
003  25  CLR
004  69  OP
005  00   00
006  03   3
007  07   7
008  03   3
009  05   5
010  02   2
011  04   4
012  01   1
013  03   3
014  03   3
015  01   1
016  69  OP
017  01   01
018  02   2
019  02   2
020  02   2
021  07   7
022  01   1
023  07   7
024  00   0
025  00   0
026  01   1
027  05   5
028  69  OP
029  02   02
030  03   3
031  02   2
032  03   3
033  00   0
034  03   3
035  03   3
036  03   3
037  06   6
038  00   0
039  00   0
040  69  OP
041  03   03
042  69  OP
043  05   05
044  02   2
045  00   0
046  00   0
047  03   3
048  06   6
049  02   2

100  03   3
101  69  OP
102  01   01
103  03   3
104  07   7
105  00   0
106  00   0
107  01   1
108  03   3
109  03   3
110  06   6
111  00   0
112  00   0
113  69  OP
114  02   02
115  02   2
116  01   1
117  03   3
118  02   2
119  02   2
120  07   7
121  02   2
122  07   7
123  03   3
124  02   2
125  69  OP
126  03   03
127  04   4
128  03   3
129  03   3
130  06   6
131  06   6
132  02   2
133  00   0
134  00   0
135  00   0
136  00   0
137  69  OP
138  04   04
139  69  OP
140  05   05
141  98  ADV
142  01   1
143  03   3
144  03   3
145  01   1
146  02   2
147  02   2
148  00   0
149  00   0

050  04   4
051  01   1
052  06   6
053  69  OP
054  01   01
055  01   1
056  07   7
057  06   6
058  03   3
059  00   0
060  00   0
061  00   0
062  03   3
063  00   0
064  00   0
065  69  OP
066  02   02
067  03   3
068  02   2
069  03   3
070  05   5
071  00   0
072  00   0
073  00   0
074  04   4
075  00   0
076  00   0
077  69  OP
078  03   03
079  01   1
080  03   3
081  03   3
082  01   1
083  02   2
084  02   2
085  03   3
086  06   6
087  69  OP
088  04   04
089  69  OP
090  05   05
091  02   2
092  01   1
093  03   3
094  02   2
095  03   3
096  05   5
097  03   3
098  00   0
099  01   1

150  01   1
151  06   6
152  69  OP
153  01   01
154  04   4
155  00   0
156  03   3
157  00   0
158  03   3
159  06   6
160  06   6
161  03   3
162  02   2
163  07   7
164  69  OP
165  02   02
166  02   2
167  04   4
168  03   3
169  01   1
170  01   1
171  07   7
172  01   1
173  03   3
174  03   3
175  05   5
176  69  OP
177  03   03
178  12   B
179  69  OP
180  05   05
181  98  ADV
182  02   2
183  04   4
184  03   3
185  01   1
186  03   3
187  03   3
188  04   4
189  01   1
190  03   3
191  07   7
192  69  OP
193  01   01
194  01   1
195  06   6
196  01   1
197  03   3
198  03   3
199  07   7
```

200	01	1	250	02	2	300	00	0	350	06	06
201	03	3	251	00	0	301	01	1	351	43	RCL
202	69	OP	252	00	0	302	03	3	352	02	02
203	02	02	253	00	0	303	03	3	353	88	DMS
204	02	2	254	02	2	304	01	1	354	42	STO
205	04	4	255	69	OP	305	69	OP	355	02	02
206	03	3	256	02	02	306	03	03	356	44	SUM
207	01	1	257	02	2	307	02	2	357	06	06
208	00	0	258	00	0	308	02	2	358	38	SIN
209	00	0	259	00	0	309	00	0	359	65	×
210	03	3	260	03	3	310	00	0	360	43	RCL
211	02	2	261	02	2	311	00	0	361	04	04
212	69	OP	262	00	0	312	02	2	362	33	X^2
213	03	03	263	00	0	313	06	6	363	65	×
214	03	3	264	04	4	314	04	4	364	43	RCL
215	05	5	265	00	0	315	00	0	365	03	03
216	01	1	266	00	0	316	01	1	366	38	SIN
217	06	6	267	69	OP	317	69	OP	367	55	÷
218	01	1	268	03	03	318	04	04	368	03	3
219	07	7	269	69	OP	319	69	OP	369	09	9
220	03	3	270	05	05	320	05	05	370	03	3
221	05	5	271	02	2	321	98	ADV	371	52	EE
222	06	6	272	04	4	322	98	ADV	372	06	6
223	02	2	273	02	2	323	98	ADV	373	95	=
224	69	OP	274	01	1	324	91	R/S	374	22	INV
225	04	04	275	00	0	325	99	PRT	375	52	EE
226	69	OP	276	00	0	326	42	STO	376	48	EXC
227	05	05	277	01	1	327	04	04	377	01	01
228	98	ADV	278	05	5	328	25	CLR	378	22	INV
229	76	LBL	279	03	3	329	91	R/S	379	67	EQ
230	89	∏	280	02	2	330	99	PRT	380	87	IFF
231	69	OP	281	69	OP	331	42	STO	381	01	1
232	00	00	282	01	01	332	01	01	382	08	8
233	03	3	283	03	3	333	91	R/S	383	00	0
234	06	6	284	01	1	334	99	PRT	384	75	-
235	02	2	285	01	1	335	42	STO	385	43	RCL
236	04	4	286	05	5	336	02	02	386	06	06
237	01	1	287	02	2	337	91	R/S	387	95	=
238	06	6	288	07	7	338	99	PRT	388	98	ADV
239	01	1	289	04	4	339	88	DMS	389	44	SUM
240	07	7	290	01	1	340	42	STO	390	06	06
241	06	6	291	01	1	341	03	03	391	86	STF
242	03	3	292	06	6	342	42	STO	392	01	01
243	69	OP	293	69	OP	343	06	06	393	76	LBL
244	01	01	294	02	02	344	43	RCL	394	87	IFF
245	01	1	295	01	1	345	01	01	395	48	EXC
246	03	3	296	07	7	346	88	DMS	396	01	01
247	03	3	297	01	1	347	42	STO	397	55	+
248	01	1	298	06	6	348	01	01	398	43	RCL
249	02	2	299	00	0	349	44	SUM	399	01	01

400	38	SIN	450	76	LBL	500	01	1	550	06	6
401	95	=	451	88	DMS	501	07	7	551	06	6
402	42	STO	452	42	STO	502	03	3	552	02	2
403	05	05	453	05	05	503	06	6	553	69	DP
404	98	ADV	454	85	+	504	69	DP	554	04	04
405	69	DP	455	01	1	505	03	03	555	69	DP
406	00	00	456	08	8	506	01	1	556	05	05
407	03	3	457	00	0	507	03	3	557	12	B
408	06	6	458	75	-	508	03	3	558	15	E
409	03	3	459	43	RCL	509	07	7	559	13	C
410	03	3	460	06	06	510	06	6	560	43	RCL
411	02	2	461	95	=	511	02	2	561	03	03
412	03	3	462	94	+/-	512	00	0	562	14	D
413	01	1	463	65	×	513	00	0	563	03	3
414	07	7	464	18	C'	514	69	DP	564	00	0
415	03	3	465	98	ADV	515	04	04	565	00	0
416	05	5	466	42	STO	516	69	DP	566	02	2
417	69	DP	467	07	07	517	05	05	567	04	4
418	01	01	468	22	INV	518	16	A'	568	03	3
419	01	1	469	58	FIX	519	43	RCL	569	06	6
420	07	7	470	03	3	520	07	07	570	06	6
421	04	4	471	07	7	521	58	FIX	571	02	2
422	04	4	472	03	3	522	02	02	572	69	DP
423	03	3	473	05	5	523	69	DP	573	04	04
424	06	6	474	02	2	524	06	06	574	69	DP
425	06	6	475	04	4	525	98	ADV	575	05	05
426	02	2	476	01	1	526	22	INV	576	12	B
427	69	DP	477	03	3	527	58	FIX	577	15	E
428	02	02	478	03	3	528	94	+/-	578	98	ADV
429	69	DP	479	01	1	529	55	÷	579	03	3
430	05	05	480	69	DP	530	18	C'	580	06	6
431	16	A'	481	01	01	531	55	÷	581	03	3
432	43	RCL	482	02	2	532	03	3	582	03	3
433	05	05	483	02	2	533	95	=	583	02	2
434	58	FIX	484	02	2	534	44	SUM	584	03	3
435	02	02	485	07	7	535	01	01	585	01	1
436	69	DP	486	01	1	536	44	SUM	586	07	7
437	06	06	487	07	7	537	02	02	587	03	3
438	22	INV	488	00	0	538	44	SUM	588	05	5
439	58	FIX	489	00	0	539	03	03	589	69	DP
440	55	÷	490	01	1	540	13	C	590	01	01
441	18	C'	491	05	5	541	43	RCL	591	02	2
442	22	INV	492	69	DP	542	02	02	592	04	4
443	87	IFF	493	02	02	543	14	D	593	01	1
444	01	01	494	02	2	544	04	4	594	05	5
445	88	DMS	495	07	7	545	00	0	595	01	1
446	44	SUM	496	03	3	546	00	0	596	03	3
447	01	01	497	02	2	547	02	2	597	02	2
448	44	SUM	498	03	3	548	04	4	598	07	7
449	06	06	499	06	6	549	03	3	599	00	0

600	00	0	650	58	FIX	700	04	04	750	05	05
601	69	OP	651	69	OP	701	69	OP	751	98	ADV
602	02	02	652	00	00	702	05	05	752	22	INV
603	01	1	653	03	3	703	04	4	753	86	STF
604	03	3	654	07	7	704	03	3	754	01	01
605	03	3	655	02	2	705	01	1	755	61	GTO
606	01	1	656	03	3	706	03	3	756	89	π
607	02	2	657	01	1	707	03	3	757	76	LBL
608	02	2	658	03	3	708	01	1	758	11	A
609	02	2	659	03	3	709	03	3	759	98	ADV
610	07	7	660	07	7	710	01	1	760	81	RST
611	01	1	661	00	0	711	01	1	761	76	LBL
612	07	7	662	00	0	712	03	3	762	12	B
613	69	OP	663	69	OP	713	69	OP	763	03	3
614	03	03	664	01	01	714	01	01	764	00	0
615	03	3	665	04	4	715	03	3	765	03	3
616	06	6	666	03	3	716	07	7	766	07	7
617	00	0	667	01	1	717	03	3	767	03	3
618	00	0	668	03	3	718	05	5	768	05	5
619	01	1	669	03	3	719	04	4	769	03	3
620	03	3	670	06	6	720	05	5	770	06	6
621	03	3	671	00	0	721	00	0	771	69	OP
622	05	5	672	00	0	722	00	0	772	04	04
623	01	1	673	01	1	723	69	OP	773	92	RTN
624	07	7	674	03	3	724	02	02	774	76	LBL
625	69	OP	675	69	OP	725	01	1	775	13	C
626	04	04	676	02	02	726	03	3	776	43	RCL
627	69	OP	677	03	3	727	03	3	777	04	04
628	05	05	678	01	1	728	01	1	778	55	÷
629	98	ADV	679	00	0	729	03	3	779	53	(
630	58	FIX	680	00	0	730	02	2	780	43	RCL
631	06	06	681	01	1	731	03	3	781	01	01
632	43	RCL	682	07	7	732	07	7	782	75	-
633	01	01	683	01	1	733	02	2	783	43	RCL
634	22	INV	684	03	3	734	03	3	784	05	05
635	88	DMS	685	03	3	735	69	OP	785	55	÷
636	99	PRT	686	06	6	736	03	03	786	03	3
637	43	RCL	687	69	OP	737	01	1	787	54	)
638	02	02	688	03	03	738	07	7	788	38	SIN
639	22	INV	689	04	4	739	03	3	789	95	=
640	88	DMS	690	05	5	740	05	5	790	65	×
641	99	PRT	691	00	0	741	00	0	791	53	(
642	43	RCL	692	00	0	742	00	0	792	92	RTN
643	03	03	693	03	3	743	07	7	793	76	LBL
644	22	INV	694	02	2	744	01	1	794	14	D
645	88	DMS	695	03	3	745	07	7	795	75	-
646	99	PRT	696	01	1	746	01	1	796	43	RCL
647	98	ADV	697	01	1	747	69	OP	797	05	05
648	98	ADV	698	07	7	748	04	04	798	55	÷
649	22	INV	699	69	OP	749	69	OP	799	03	3

```
800  54  )
801  38  SIN
802  95  =
803  42  STO
804  07  07
805  01  1
806  05  5
807  03  3
808  02  2
809  03  3
810  00  0
811  03  3
812  03  3
813  00  0
814  00  0
815  69  OP
816  01  01
817  03  3
818  06  6
819  02  2
820  04  4
821  01  1
822  06  6
823  01  1
824  07  7
825  00  0
826  00  0
827  69  OP
828  02  02
829  02  2
830  00  0
831  00  0
832  03  3
833  07  7
834  03  3
835  02  2
836  00  0
837  00  0
838  69  OP
839  03  03
840  92  RTN
841  76  LBL
842  15  E
843  43  RCL
844  07  07
845  58  FIX
846  04  04
847  69  OP
848  06  06
849  98  ADV
850  22  INV
851  58  FIX
852  69  OP
853  00  00
854  92  RTN
855  76  LBL
856  16  A'
857  69  OP
858  00  00
859  03  3
860  06  6
861  01  1
862  07  7
863  01  1
864  05  5
865  03  3
866  06  6
867  69  OP
868  04  04
869  92  RTN
870  76  LBL
871  18  C'
872  03  3
873  06  6
874  00  0
875  00  0
876  95  =
877  92  RTN
878  00  0
879  00  0
```

APPENDIX B

SOLUTION OF THE GEODETIC PROBLEM

Purpose: Reference TM 5-237, Surveying Computer's Manual, 1964 Pp. 175, 181; Paragraphs 67-69, 70-72.

The purpose of this program is to provide solutions to the direct and reverse geodetic problems. It has been structured to provide instructions for the call-up of required instruction sets, input data for use with varied ellipsoids, and for the input of information required for the solution to geodetic problems.

Direct Problem: Given the latitude and longitude of the standpoint and the azimuth and distance from the standpoint to the forepoint, this program computes the latitude and longitude of the forepoint and the azimuth from the forepoint to the standpoint.

Reverse Problem: Given the latitudes and the longitudes of two stations, this program computes the distance and forward and reverse azimuths between the two stations.

NOTES:

1. This program has been designed for use with a TI Printer (PC-100 Series).
2. Program constants are metric, therefore, input/output values for distance must be in meters.
3. Angular values are input as one numerical entry with a decimal point

placed between the degrees and minutes values.

4. When inversing stations within 200 meters of each other some degradation of absolute azimuth will occur, but the relative accuracy is maintained. Distances are computed to an accuracy of two millimeters.

INSTRUCTIONS and INPUTS/OUTPUTS:

1. Printer "ON" and, then, Calculator "ON".
2. Load the four sides of the magnetic cards:
   a. CLR, RST, 1, 2nd OP 17, INV, 2nd, WRITE; Enter Side 1.
   b. 2, INV, 2nd, WRITE; Enter Side 2.
   c. 3, INV, 2nd, WRITE; Enter Side 3.
   d. 4, INV, 2nd, WRITE; Enter Side 4.

   If a blinking number appears after a side has been fed through the calculator, repeat the action, starting at CLR, for that side. Refer to operating instructions maual if difficulty occurs.
3. Depress "A" for information and instructions:
   a. Title of program and constants.
   b. Depress "E" to input new constants or go to next instruction (See also paragraph 4).
   c. Depress "B" to use the program for a direct solution or depress "C" to use the program for reverse solution.
   d. After any solution has been computed, it is not necessary to depress the user label to repeat the same type solution. If new constants are to be entered or another type solution is desired, it is necessary to depress the applicable user label.

4. The following constants are associated with the listed ellipsoids:

Ellipsoid	1/E*	C **
International	147.750	6 399 936.606
Bessel	148.827	6 398 786.846
Everest	149.651	6 398 547.992
Clarke 1880	145.983	6 400 857.735
Australian Nat.	148.357	6 399 617.223
Mercury 1960	148.400	6 399 619.635
Fischer, SE Asia	148.400	6 399 608.600
Hough 1960	147.750	6 399 818.210
Airy	148.913	6 398 941.304
Krassovsky	148.400	6 399 698.900
NWL 9 D	148.380	6 399 602.200

* $1/E = (1-f)^2 / (2f-f^2)$

* * $C = a/(1-f)$

Where: a = equatorial radius

f = reciprocal of the flattening

5. The sign convention for input/output geodetic coordinates are as follows:

	Positive	Negative
Latitude :	North	South
Longitude :	West	East

6. For longitudinal values in excess of one-hundred degrees, subtract one-hundred degrees from the absolute degrees value before input and add one-hundred degrees to the absolute degrees value after output.

Example: Input 125° as 25°
Add 100° back to output longitude

Input -125° as -25°
Subtract 100° from output longitude

INPUT DATA:

1. Direct Problem (Position Computation)
   a. Latitude (1): N (+), S(-).
   b. Longitude (1): W(+), E(-).
   c. Azimuth (Clockwise from 0^{o} North).
   d. Distance, Station 1 to Station 2, in meters.
2. Reverse Problem (Inverse Position Computation)
   a. Latitude (1): N(+), S(-).
   b. Longitude (1): W(+), E(-).
   c. Latitude (2): N(+), S(-).
   d. Longitude (2): W(+), E(-).
3. New Constants (See listing of ellipsoids).
   a. "C".
   b. "1/E".

FORMULATION and COMPUTATION:

1. Change steps 28 - 26 and 45 - 58 for use with other ellipsoids.
2. Angles are in radians in the following formulas:

$$\theta = s/c \qquad \phi_m = \phi_1 + \tfrac{1}{2}\theta\cos\alpha_{12}$$

$$V_m^2 = 1 + \varepsilon\cos^2\phi_m \qquad e = \tfrac{1}{2}\theta^2 V_m^4 \sin\alpha_{12}\cos\alpha_{12}$$

$$\phi_2' = 2\phi_m - \phi_1 \qquad \eta = e\tan\alpha_{12}\tan\phi_2'$$

$$\phi_2 = \phi_1 + \theta V_m^3 \cos(\alpha_{12} - \tfrac{3}{2}e) - \eta$$

$$\lambda_2 = \lambda_1 - \theta V_2 \sin(\alpha_{12} - \tfrac{1}{2}e)(\sec(\phi_2 + \tfrac{1}{3}\eta))$$

$$\text{where } V_2 = (1 + \varepsilon\cos^2\phi_2)^{1/2}$$

$$\alpha_{21} = \alpha_{12} \pm \pi \pm (\Delta\lambda \sin\phi_m) \qquad \text{North} = 0^\circ A_3.$$

η is the angular distance along the meridian of P_1 from ϕ_2 to the foot of the perpendicular from P_2.

This formula uses the azimuth of the normal section, not the azimuth of the geodesic. The difference between the two is negligible (<0.028 at 100 KM)

INVERSE SOLUTION

Source of Equations: H. F. Rainsford's formula as given in Empire Survey Review 71, 1949. Terms beyond third order have been omitted and fourth order elliptic terms have been omitted from third order terms. Expansions are used in terms of $\xi = \Delta\phi$ and $\eta = \Delta\lambda \cos\phi$. All angles are in radians. Longitude is positive east.

c = polar radius

ε = the square of second eccentricity

$\phi = (1/2)(\phi_1 + \phi_2)$

$\xi = (\phi_2 - \phi_1)$

$\eta = (\lambda_2 - \lambda_1)\cos\phi$

$t = \tan\phi$

$D = \varepsilon \cos^2\phi$

$V^2 = 1 + D$

$A_1 = (1/8)\ D\ (1 - t^2)$

$B_1 = -(1/24)(2 + 3t^2 + 2D)$

$A_2 = (1/24)(1 - D(1 + 9t^2))$

$B_2 = -(1/24)t^2$

$A_3 = (1/24)(3 + 2D)$

$B_3 = (1/12)(1 + D)$

$x = (\xi/V^3)(1 + A_1\xi^2 + B_1\eta^2)$

$y = (\eta/V)(1 + A_2\xi^2 + B_2\eta^2)$

$z = t\eta(1 + A_3\xi^2 + B_3\eta^2)$

$S = c\sqrt{x^2 + y^2} = cr$

$\tan A = y/x$ or $\cot A = x/y$

$\alpha_{12} = A - (1/2)z$

$\alpha_{21} = A + (1/2)z \pm \pi$

These equations give an accuracy of about 1:10^8 up to 200 km or more in low and medium latitudes, up to 160 km at latitude 60°, and progressively less in higher latitudes.

SAMPLE RUNS

```
POSITION AND INVERSE
   6399902.6        =C
      146.74        =1/E

E: FOR NEW CONSTANTS
B: DIRECT/C: INVERSE
```

```
INPUT                C:1/E


  63998999.5
      148.23
B: DIRECT/C: INVERSE
```

```
DIRCT COMP      INPUT
LAT1/LON1:AZ/N:DIS/M


 30.12131234
 75.10154321
  60.2609155
    11061.08


          30.
          15.
    10.22220


          75.
           4.
    15.55550


         240.
          29.
     10.333
```

```
INVRS COMP      INPUT
LAT1/LON1: LAT2/LON2


 30.12131234
 75.10154321

 30.15102222
 75.04155555


          60.
          26.
       9.157


         240.
          29.
      10.335

  11061.0796
```

PROGRAM LISTING

```
000  98 ADV
001  03  3
002  03  3
003  03  3
004  02  2
005  03  3
006  06  6
007  02  2
008  04  4
009  03  3
010  07  7
011  69 DP
012  01  01
013  02  2
014  04  4
015  03  3
016  02  2
017  03  3
018  01  1
019  00  0
020  00  0
021  01  1
022  03  3
023  69 DP
024  02  02
025  03  3
026  01  1
027  01  1
028  06  6
029  00  0
030  00  0
031  02  2
032  04  4
033  03  3
034  01  1
035  69 DP
036  03  03
037  04  4
038  02  2
039  01  1
040  07  7
041  03  3
042  05  5
043  03  3
044  06  6
045  01  1
046  07  7
047  69 DP
048  04  04
049  69 DP
050  05  05
051  06  6
052  04  4
053  01  1
054  05  5
055  69 DP
056  04  04
057  06  6
058  03  3
059  09  9
060  09  9
061  09  9
062  00  0
063  02  2
064  93  .
065  06  6
066  42 STO
067  09  09
068  69 DP
069  06  06
070  06  6
071  04  4
072  00  0
073  02  2
074  06  6
075  03  3
076  01  1
077  07  7
078  69 DP
079  04  04
080  01  1
081  04  4
082  06  6
083  93  .
084  07  7
085  04  4
086  42 STO
087  08  08
088  69 DP
089  06  06
090  01  1
091  07  7
092  06  6
093  02  2
094  00  0
095  00  0
096  02  2
097  01  1
098  03  3
099  02  2
100  69 DP
101  01  01
102  03  3
103  05  5
104  00  0
105  00  0
106  03  3
107  01  1
108  01  1
109  07  7
110  04  4
111  03  3
112  69 DP
113  02  02
114  01  1
115  05  5
116  03  3
117  02  2
118  03  3
119  01  1
120  03  3
121  06  6
122  69 DP
123  03  03
124  03  3
125  07  7
126  01  1
127  03  3
128  03  3
129  01  1
130  03  3
131  07  7
132  03  3
133  06  6
134  69 DP
135  04  04
136  98 ADV
137  69 DP
138  05  05
139  76 LBL
140  88 DMS
141  01  1
142  04  4
143  06  6
144  02  2
145  00  0
146  00  0
147  01  1
148  06  6
149  02  2
150  04  4
151  69 DP
152  01  01
153  03  3
154  05  5
155  01  1
156  07  7
157  01  1
158  05  5
159  03  3
160  07  7
161  06  6
162  03  3
163  69 DP
164  02  02
165  01  1
166  05  5
167  06  6
168  02  2
169  00  0
170  00  0
171  02  2
172  04  4
173  03  3
174  01  1
175  69 DP
176  03  03
177  04  4
178  02  2
179  01  1
180  07  7
181  03  3
182  05  5
183  03  3
184  06  6
185  01  1
186  07  7
187  69 DP
188  04  04
189  69 DP
190  05  05
191  98 ADV
192  98 ADV
193  98 ADV
194  25 CLR
195  91 R/S
196  76 LBL
197  30 TAN
198  87 IFF
199  01  01
```

200	38	SIN	250	01	01	300	34	fX	350	43	RCL
201	76	LBL	251	91	R/S	301	42	STO	351	05	05
202	39	COS	252	99	PRT	302	04	04	352	95	=
203	14	D	253	42	STO	303	02	2	353	42	STO
204	02	2	254	03	03	304	00	0	354	00	00
205	04	4	255	98	ADV	305	42	STO	355	32	X:T
206	03	3	256	91	R/S	306	05	05	356	43	RCL
207	01	1	257	99	PRT	307	85	+	357	00	00
208	04	4	258	42	STO	308	03	3	358	33	X^2
209	02	2	259	02	02	309	65	×	359	42	STO
210	03	3	260	91	R/S	310	43	RCL	360	06	06
211	05	5	261	99	PRT	311	02	02	361	02	2
212	03	3	262	94	+/-	312	33	X^2	362	85	+
213	06	6	263	10	E'	313	85	+	363	03	3
214	69	DP	264	48	EXC	314	02	2	364	65	×
215	01	01	265	03	03	315	65	×	365	16	A'
216	19	D'	266	10	E'	316	17	B'	366	33	X^2
217	02	2	267	44	SUM	317	33	X^2	367	95	=
218	07	7	268	03	03	318	95	=	368	65	×
219	01	1	269	16	A'	319	55	÷	369	17	B'
220	03	3	270	10	E'	320	02	2	370	33	X^2
221	03	3	271	42	STO	321	65	×	371	75	-
222	07	7	272	01	01	322	16	A'	372	43	RCL
223	00	0	273	48	EXC	323	65	×	373	05	05
224	03	3	274	02	02	324	17	B'	374	95	=
225	69	DP	275	10	E'	325	55	÷	375	65	×
226	03	03	276	22	INV	326	43	RCL	376	43	RCL
227	06	6	277	44	SUM	327	05	05	377	02	02
228	03	3	278	02	02	328	95	=	378	55	÷
229	02	2	279	85	+	329	42	STO	379	43	RCL
230	07	7	280	16	A'	330	07	07	380	04	04
231	03	3	281	95	=	331	43	RCL	381	45	Y^X
232	02	2	282	55	÷	332	02	02	382	03	3
233	03	3	283	02	2	333	33	X^2	383	55	÷
234	01	1	284	95	=	334	75	-	384	43	RCL
235	00	0	285	30	TAN	335	16	A'	385	05	05
236	03	3	286	42	STO	336	33	X^2	386	95	=
237	69	DP	287	01	01	337	65	×	387	42	STO
238	04	04	288	22	INV	338	17	B'	388	03	03
239	69	DP	289	30	TAN	339	33	X^2	389	22	INV
240	05	05	290	39	COS	340	85	+	390	37	P/R
241	76	LBL	291	49	PRD	341	43	RCL	391	94	+/-
242	33	X^2	292	03	03	342	05	05	392	85	+
243	98	ADV	293	33	X^2	343	95	=	393	89	π
244	98	ADV	294	55	÷	344	55	÷	394	55	÷
245	98	ADV	295	43	RCL	345	43	RCL	395	02	2
246	25	CLR	296	08	08	346	04	04	396	95	=
247	91	R/S	297	85	+	347	65	×	397	42	STO
248	99	PRT	298	01	1	348	17	B'	398	02	02
249	42	STO	299	95	=	349	55	÷	399	75	-

```
400  43 RCL
401  07  07
402  95  =
403  86 STF
404  02  02
405  18 C'
406  25 CLR
407  32 X:T
408  43 RCL
409  02  02
410  75  -
411  89  π
412  85  +
413  43 RCL
414  07  07
415  95  =
416  86 STF
417  02  02
418  18 C'
419  17 B'
420  33 X²
421  85  +
422  43 RCL
423  06  06
424  95  =
425  34 ΓX
426  65  ×
427  43 RCL
428  09  09
429  95  =
430  58 FIX
431  04  04
432  98 ADV
433  99 PRT
434  22 INV
435  58 FIX
436  22 INV
437  87 IFF
438  01  01
439  33 X²
440  76 LBL
441  38 SIN
442  14  D
443  01  1
444  06  6
445  02  2
446  04  4
447  03  3
448  05  5
449  01  1

450  05  5
451  03  3
452  07  7
453  69 DP
454  01  01
455  19 D'
456  01  1
457  03  3
458  04  4
459  06  6
460  06  6
461  03  3
462  03  3
463  01  1
464  06  6
465  02  2
466  69 DP
467  03  03
468  01  1
469  06  6
470  02  2
471  04  4
472  03  3
473  06  6
474  06  6
475  03  3
476  03  3
477  00  0
478  69 DP
479  04  04
480  69 DP
481  05  05
482  76 LBL
483  34 ΓX
484  98 ADV
485  98 ADV
486  98 ADV
487  25 CLR
488  91 R/S
489  99 PRT
490  42 STO
491  01  01
492  91 R/S
493  99 PRT
494  42 STO
495  02  02
496  91 R/S
497  99 PRT
498  42 STO
499  03  03

500  91 R/S
501  99 PRT
502  55  ÷
503  43 RCL
504  09  09
505  95  =
506  42 STO
507  04  04
508  16 A'
509  10 E'
510  42 STO
511  01  01
512  43 RCL
513  02  02
514  10 E'
515  42 STO
516  02  02
517  17 B'
518  10 E'
519  42 STO
520  03  03
521  39 COS
522  65  ×
523  43 RCL
524  04  04
525  55  ÷
526  02  2
527  85  +
528  16 A'
529  95  =
530  42 STO
531  00  00
532  39 COS
533  33 X²
534  55  ÷
535  43 RCL
536  08  08
537  85  +
538  01  1
539  95  =
540  34 ΓX
541  42 STO
542  05  05
543  33 X²
544  33 X²
545  65  ×
546  43 RCL
547  04  04
548  33 X²
549  65  ×

550  17 B'
551  38 SIN
552  65  ×
553  17 B'
554  39 COS
555  95  =
556  42 STO
557  06  06
558  65  ×
559  17 B'
560  30 TAN
561  65  ×
562  53  (
563  02  2
564  65  ×
565  43 RCL
566  00  00
567  75  -
568  16 A'
569  54  )
570  30 TAN
571  95  =
572  42 STO
573  07  07
574  94 +/-
575  55  ÷
576  02  2
577  85  +
578  16 A'
579  85  +
580  53  (
581  43 RCL
582  05  05
583  45 Y^x
584  03  3
585  65  ×
586  43 RCL
587  04  04
588  65  ×
589  53  (
590  17 B'
591  75  -
592  43 RCL
593  06  06
594  55  +
595  03  3
596  54  )
597  39 COS
598  95  =
599  42 STO
```

600	01	01	650	04	04	700	76	LBL	750	59	INT
601	18	C'	651	85	+	701	10	E'	751	99	PRT
602	43	RCL	652	17	B'	702	88	DMS	752	94	+/-
603	01	01	653	75	-	703	65	×	753	85	+
604	39	COS	654	03	3	704	89	π	754	43	RCL
605	33	X^2	655	65	×	705	55	÷	755	05	05
606	55	÷	656	89	π	706	01	1	756	65	×
607	43	RCL	657	95	=	707	08	8	757	01	1
608	08	08	658	86	STF	708	00	0	758	00	0
609	85	+	659	02	02	709	95	=	759	00	0
610	01	1	660	18	C'	710	92	RTN	760	95	=
611	95	=	661	87	IFF	711	76	LBL	761	65	×
612	34	$\sqrt{X}$	662	01	01	712	18	C'	762	01	1
613	65	×	663	34	$\sqrt{X}$	713	98	ADV	763	00	0
614	43	RCL	664	76	LBL	714	76	LBL	764	00	0
615	04	04	665	11	A	715	44	SUM	765	95	=
616	65	×	666	47	CMS	716	77	GE	766	87	IFF
617	53	(	667	70	RAD	717	35	1/X	767	02	02
618	17	B'	668	14	D	718	85	+	768	70	RAD
619	75	-	669	81	RST	719	02	2	769	58	FIX
620	43	RCL	670	76	LBL	720	65	×	770	05	05
621	06	06	671	12	B	721	89	π	771	61	GTO
622	55	÷	672	86	STF	722	95	=	772	22	INV
623	06	6	673	01	01	723	61	GTO	773	76	LBL
624	54	)	674	61	GTO	724	44	SUM	774	70	RAD
625	38	SIN	675	30	TAN	725	76	LBL	775	58	FIX
626	55	÷	676	76	LBL	726	35	1/X	776	03	03
627	53	(	677	13	C	727	65	×	777	76	LBL
628	16	A'	678	22	INV	728	01	1	778	22	INV
629	85	+	679	86	STF	729	08	8	779	99	PRT
630	43	RCL	680	01	01	730	00	0	780	22	INV
631	07	07	681	61	GTO	731	55	÷	781	58	FIX
632	55	÷	682	30	TAN	732	89	π	782	22	INV
633	06	6	683	76	LBL	733	95	=	783	86	STF
634	54	)	684	14	D	734	22	INV	784	02	02
635	39	COS	685	22	INV	735	88	DMS	785	92	RTN
636	95	=	686	58	FIX	736	42	STO	786	76	LBL
637	42	STO	687	69	DP	737	05	05	787	19	D'
638	04	04	688	00	00	738	59	INT	788	01	1
639	94	+/-	689	92	RTN	739	99	PRT	789	05	5
640	85	+	690	76	LBL	740	22	INV	790	03	3
641	43	RCL	691	16	A'	741	44	SUM	791	02	2
642	02	02	692	43	RCL	742	05	05	792	03	3
643	95	=	693	01	01	743	43	RCL	793	00	0
644	18	C'	694	92	RTN	744	05	05	794	03	3
645	43	RCL	695	76	LBL	745	65	×	795	03	3
646	00	00	696	17	B'	746	01	1	796	69	DP
647	38	SIN	697	43	RCL	747	00	0	797	02	02
648	65	×	698	03	03	748	00	0	798	02	2
649	43	RCL	699	92	RTN	749	95	=	799	04	4

800	03	3
801	01	1
802	03	3
803	03	3
804	04	4
805	01	1
806	03	3
807	07	7
808	69	DP
809	04	04
810	69	DP
811	05	05
812	02	2
813	07	7
814	01	1
815	03	3
816	03	3
817	07	7
818	00	0
819	02	2
820	06	6
821	03	3
822	69	DP
823	01	01
824	02	2
825	07	7
826	03	3
827	02	2
828	03	3
829	01	1
830	00	0
831	02	2
832	06	6
833	02	2
834	69	DP
835	02	02
836	92	RTN
837	76	LBL
838	15	E
839	14	D
840	02	2
841	04	4
842	03	3
843	01	1
844	03	3
845	03	3
846	04	4
847	01	1
848	03	3
849	07	7
850	69	DP
851	01	01
852	01	1
853	05	5
854	06	6
855	02	2
856	00	0
857	02	2
858	06	6
859	03	3
860	01	1
861	07	7
862	69	DP
863	04	04
864	69	DP
865	05	05
866	98	ADV
867	98	ADV
868	98	ADV
869	25	CLR
870	91	R/S
871	99	PRT
872	42	STO
873	09	09
874	91	R/S
875	99	PRT
876	42	STO
877	08	08
878	61	GTO
879	88	DMS

APPENDIX C

REDUCTION TO CENTER

Purpose: Reference TM 5-237, Surveying Computer's Manual, 1964 Page 133 Paragraph 56 a

The computation of the eccentric reduction provides the correction which, when properly applied to the observed direction, reduces it to the value it would have been had the instrument or target or both not been eccentric.

NOTES:

1. This program is designed to be used with the TI Printer (PC-100 Series). Simple modification of the program will provide stop/output for a TI 59 calculator without a printer attachment.
2. The values of the known lengths may be entered in any consistent linear system.
3. The angular value at the occupied station from the near station to the distant station is input as one numerical value with a decimal point placed between the degrees and minutes values.

INSTRUCTIONS:

1. Printer "ON", and, then, Calculator "ON".
2. Load the two sides of the magnetic card.
   a. CLR, RST, 1, 2nd, OP 17, 1, INV, 2nd, WRITE; Enter Side 1.
   b. 2; Enter Side 2.

Note: The underlined numbers may be replaced by zeroes. Refer to the operating instruction manual if difficulty occurs.

3. Depress "A" for initialization and input instruction.

4. For explanation of "cases", depress "B", then after the information is provided, depress "A" for input and computations.

5. Computed/output values will be followed by a print of the station number and "d". If either a new station or a new "d" is to be used, depress "A" and input a complete set of data.

INPUT DATA:

1. Station ID number.

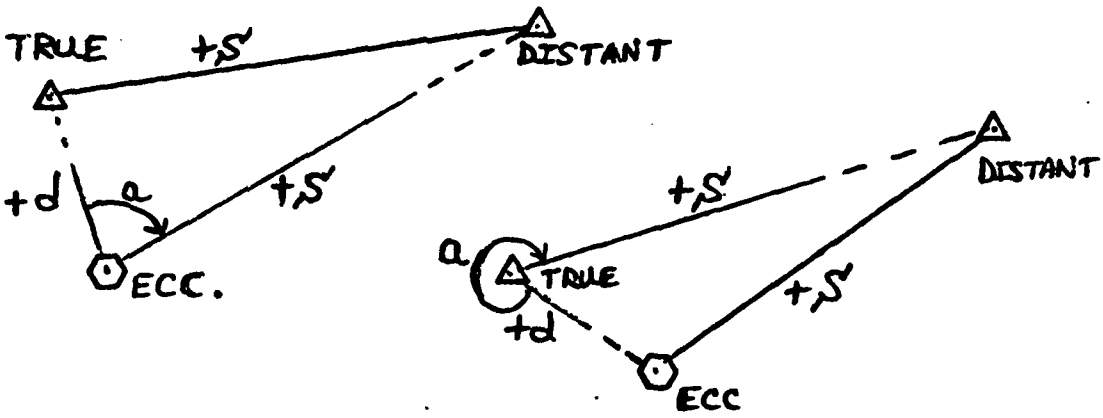
2. "d": Distance between True and Eccentric stations, in meters.

3. Case number.

4. Distance, in meters, from the True or Eccentric station to the far station (according to case number).

5. Clockwise angle at the occupied station from the near station to the far station.

FORMULATION and COMPUTATION:



Note: In like figures the eccentric and swing angles are numerically equal, but opposite in sign.

$$\text{Angle (Seconds)} = \sin^{-1} \frac{(d \sin a)}{S}$$

When two sides and the included angle comprise the input data, the law of cosines is utilized to compute the side opposite the observed station and, then, that value is used in the law of sines (above).

SAMPLE RUNS

CASE NO.	LENGTH TO FAR STA	LENGTH TO NEAR STA	STA DCC
1	TRU		TRU
2		ECC	TRU
3	TRU		ECC
4		ECC	ECC

1,3 SWG/2,4 RED ANG

INPUT FOR ECC RED
STA/D//CASE/DIST/ANG

101.

1.54

1.

13000. 276
280.

-24.06 SECS

101.

1.54

2.

13000. 276
99.593594

24.06 SECS

101.

1.54

3.

13000.
280.

-24.06 SECS

101.

1.54

4.

13000.
99.593594

24.06 SECS

101.

1.54

000	25	CLR	050	67	EQ	100	07	7	150	01	1
001	22	INV	051	34	$\sqrt{x}$	101	01	1	151	07	7
002	58	FIX	052	43	RCL	102	05	5	152	01	1
003	98	ADV	053	01	01	103	03	3	153	05	5
004	98	ADV	054	33	x^2	104	06	6	154	01	1
005	98	ADV	055	85	+	105	69	DP	155	05	5
006	91	R/S	056	43	RCL	106	04	04	156	69	DP
007	42	STO	057	03	03	107	43	RCL	157	03	03
008	07	07	058	33	x^2	108	08	08	158	03	3
009	99	PRT	059	75	-	109	98	ADV	159	05	5
010	91	R/S	060	43	RCL	110	58	FIX	160	01	1
011	42	STO	061	01	01	111	02	02	161	07	7
012	01	01	062	65	×	112	69	DP	162	01	1
013	76	LBL	063	43	RCL	113	06	06	163	06	6
014	38	SIN	064	03	03	114	22	INV	164	69	DP
015	43	RCL	065	65	×	115	58	FIX	165	04	04
016	01	01	066	43	RCL	116	43	RCL	166	69	DP
017	98	ADV	067	04	04	117	07	07	167	05	05
018	99	PRT	068	39	COS	118	98	ADV	168	03	3
019	98	ADV	069	65	×	119	98	ADV	169	06	6
020	98	ADV	070	02	2	120	98	ADV	170	03	3
021	98	ADV	071	95	=	121	99	PRT	171	07	7
022	91	R/S	072	34	$\sqrt{x}$	122	61	GTO	172	01	1
023	42	STO	073	42	STO	123	38	SIN	173	03	3
024	06	06	074	05	05	124	76	LBL	174	06	6
025	99	PRT	075	76	LBL	125	11	A	175	03	3
026	98	ADV	076	34	$\sqrt{x}$	126	22	INV	176	01	1
027	91	R/S	077	43	RCL	127	58	FIX	177	06	6
028	42	STO	078	01	01	128	69	DP	178	69	DP
029	03	03	079	65	×	129	00	00	179	01	01
030	42	STO	080	43	RCL	130	02	2	180	06	6
031	05	05	081	04	04	131	04	4	181	03	3
032	99	PRT	082	38	SIN	132	03	3	182	06	6
033	91	R/S	083	55	÷	133	01	1	183	03	3
034	99	PRT	084	43	RCL	134	03	3	184	01	1
035	88	DMS	085	05	05	135	03	3	185	05	5
036	42	STO	086	95	=	136	04	4	186	01	1
037	04	04	087	22	INV	137	01	1	187	03	3
038	43	RCL	088	38	SIN	138	03	3	188	03	3
039	06	06	089	65	×	139	07	7	189	06	6
040	75	-	090	03	3	140	69	DP	190	69	DP
041	02	2	091	06	6	141	01	01	191	02	02
042	95	=	092	00	0	142	02	2	192	01	1
043	67	EQ	093	00	0	143	01	1	193	07	7
044	34	$\sqrt{x}$	094	95	=	144	03	3	194	06	6
045	43	RCL	095	42	STO	145	02	2	195	03	3
046	06	06	096	08	08	146	03	3	196	01	1
047	75	-	097	03	3	147	05	5	197	06	6
048	03	3	098	06	6	148	69	DP	198	02	2
049	95	=	099	01	1	149	02	02	199	04	4

200	03	3
201	06	6
202	69	DP
203	03	03
204	03	3
205	07	7
206	06	6
207	03	3
208	01	1
209	03	3
210	03	3
211	01	1
212	02	2
213	02	2
214	69	DP
215	04	04
216	69	DP
217	05	05
218	47	CMS
219	81	RST
220	00	0
221	00	0
222	00	0
223	00	0
224	00	0
225	00	0
226	00	0
227	00	0
228	00	0
229	00	0
230	00	0
231	00	0
232	00	0
233	00	0
234	00	0
235	00	0
236	00	0
237	00	0
238	00	0
239	00	0
240	01	1
241	05	5
242	01	1
243	03	3
244	03	3
245	06	6
246	01	1
247	07	7
248	06	6
249	02	2

250	69	DP
251	01	01
252	02	2
253	07	7
254	01	1
255	07	7
256	03	3
257	01	1
258	02	2
259	02	2
260	69	DP
261	02	02
262	03	3
263	07	7
264	02	2
265	03	3
266	00	0
267	00	0
268	03	3
269	07	7
270	03	3
271	02	2
272	69	DP
273	03	03
274	06	6
275	02	2
276	03	3
277	06	6
278	03	3
279	07	7
280	01	1
281	03	3
282	69	DP
283	04	04
284	69	DP
285	05	05
286	03	3
287	01	1
288	03	3
289	02	2
290	04	4
291	00	0
292	06	6
293	02	2
294	69	DP
295	01	01
296	02	2
297	01	1
298	01	1
299	03	3

300	03	3
301	05	5
302	69	DP
303	02	02
304	03	3
305	06	6
306	03	3
307	07	7
308	01	1
309	03	3
310	69	DP
311	03	03
312	06	6
313	02	2
314	03	3
315	02	2
316	01	1
317	05	5
318	01	1
319	05	5
320	69	DP
321	04	04
322	69	DP
323	05	05
324	98	ADV
325	69	DP
326	00	00
327	00	0
328	02	2
329	69	DP
330	01	01
331	03	3
332	07	7
333	03	3
334	05	5
335	04	4
336	01	1
337	69	DP
338	02	02
339	03	3
340	07	7
341	03	3
342	05	5
343	04	4
344	01	1
345	69	DP
346	04	04
347	69	DP
348	05	05
349	69	DP

350	00	00
351	00	0
352	03	3
353	69	DP
354	01	01
355	01	1
356	07	7
357	01	1
358	05	5
359	01	1
360	05	5
361	69	DP
362	03	03
363	03	3
364	07	7
365	03	3
366	05	5
367	04	4
368	01	1
369	69	DP
370	04	04
371	69	DP
372	05	05
373	69	DP
374	00	00
375	00	0
376	04	4
377	69	DP
378	01	01
379	03	3
380	07	7
381	03	3
382	05	5
383	04	4
384	01	1
385	69	DP
386	02	02
387	01	1
388	07	7
389	01	1
390	05	5
391	01	1
392	05	5
393	69	DP
394	04	04
395	69	DP
396	05	05
397	69	DP
398	00	00
399	00	0

```
400  05  5
401  69  DP
402  01  01
403  01  1
404  07  7
405  01  1
406  05  5
407  01  1
408  05  5
409  69  DP
410  03  03
411  01  1
412  07  7
413  01  1
414  05  5
415  01  1
416  05  5
417  69  DP
418  04  04
419  69  DP
420  05  05
421  98  ADV
422  98  ADV
423  00  0
424  02  2
425  05  5
426  07  7
427  00  0
428  04  4
429  00  0
430  00  0
431  03  3
432  06  6
433  69  DP
434  01  01
435  04  4
436  03  3
437  02  2
438  02  2
439  06  6
440  03  3
441  00  0
442  03  3
444  07  7
445  69  DP
446  02  02
447  00  0
448  05  5
449  00  0
```

```
450  00  0
451  03  3
452  05  5
453  01  1
454  07  7
455  01  1
456  06  6
457  69  DP
458  03  03
459  01  1
460  03  3
461  03  3
462  01  1
463  02  2
464  02  2
465  69  DP
466  04  04
467  69  DP
468  05  05
469  98  ADV
470  98  ADV
471  98  ADV
472  91  R/S
473  76  LBL
474  12  B
475  61  GTO
476  02  02
477  40  40
478  00  0
479  00  0
```

APPENDIX D

REDUCTION OF SLOPED DISTANCE TO SEA LEVEL DISTANCE USING RECIPROCAL VERTICAL ANGLE OBSERVATIONS

Purpose: Reference TM 5-237, Surveying Computer's Manual, 1964 Page 112, Paragraph 48.

Observed or known sloped distances must be reduced to a horizontal (geodetic) length, usually at sea level, for use in the solution of triangulation data.

This program reduces sloped distances to sea level or ellipsoid lengths depending on the height used. It is designed for use with station-to-station or electronically measured sloped distance.

NOTES:

1. This program has been designed for use with the TI Printer (PC-100 Series). Simple modifications of the program are possible which will provide stop/output for a TI-59 calculator without a printer attachment.
2. Program constants are metric, therefore, input/output linear values must be in meters.
3. Angular values are input as one numerical entry with a decimal point placed between the degrees and minutes values.

INSTRUCTIONS:

1. Printer "ON" and, then Calculator "ON".
2. Load the four sides of the magnetic cards:

a. CLR, RST, 2, 2nd, CP, 17, 1, INV, 2nd, WRITE; Enter Side 1.

b. 2; Enter Side 2.

c. 3; Enter Side 3.

d. 4; Enter Side 4.

Note: The numbers that are underlined may be replaced by zeroes. Refer to operating instruction manual if difficulty occurs.

3. Depress "A" for initialization and instructions.

4. Reference: EDME: "H1/H2 ABV STA."

a. If EDME measurement, enter heights of instruments/targets above their respective stations (1 or 2).

b. If sloped distance is station to station, enter zeroes for H1 and H2.

INPUT DATA:

1. Latitude (mean of the two stations): N (+), S(-).

2. Azimuth (from station 1 to station 2): Clockwise from 0^{o} North.

3. Vertical Angle at station 1 to station 2.

4. Vertical Angle at station 2 to station 1.

5. Height of theodolite above station 1, in meters.

6. Height of target above station 2, in meters.

7. Height of theodolite above station 2, in meters.

8. Height of target above station 1, in meters.

9. Sloped distance: station 1 to station 2, in meters.

10. Elevation of station 1, in meters.

11. EDME Heights (or zeroes if sloped distance is from station disk to station disk.

a. Height of instrument or reflector/slave-unit above station 1, in meters.

b. Height of instrument oor reflector/slave-unit above station 2, in meters.

FORMULATION and COMPUTATION:

These formulas were derived by T. Vincenty for use with small calculators.

1. Angles are in radian measure in the following formulas.

2. Vertical angles are Positive upwards from the horizon.

3. Vertical angles are corrected for heights of theodolite (t) and targets (o) by (t-o)/L within the program.

$$h_2 = h_1 + \Delta h = h_1 + L \sin V$$
where $V = \frac{1}{2}(v_1 - v_2)$; ($v_1$ & v_2 = corrected angles).

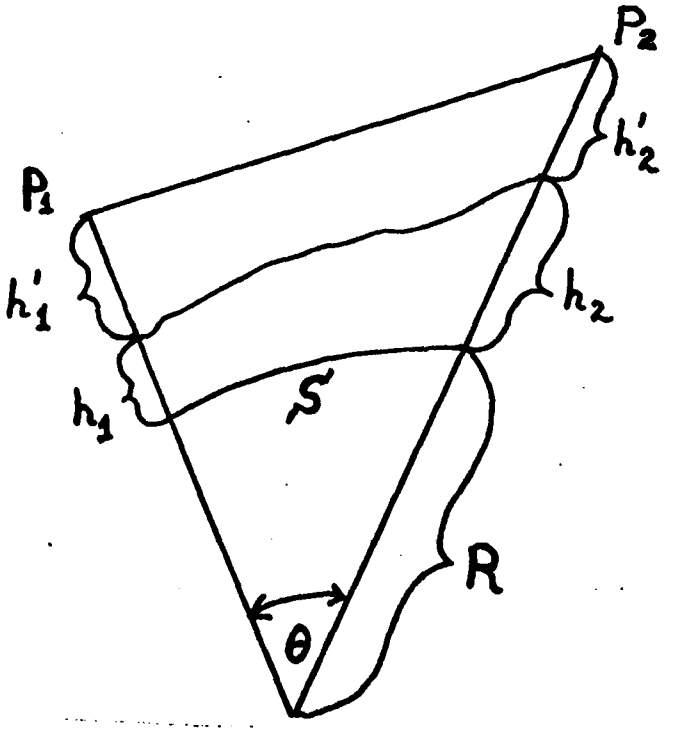
$$S = s' - \Delta h'(\Delta h + \tfrac{1}{2}\Delta h')/s'$$
where $\Delta h' = h'_2 - h'_1$

and where $$s' = \sqrt{\frac{L^2 - \Delta h^2}{1 + \frac{h_1 + h_2}{R}}}$$

Where $$R = 6400000\left[1 - \left(\frac{\cos^2\phi}{295}\right)(1 + 2\cos^2\alpha)\right]$$

SBR "B" applies ellipsoid curvature correction and a correction to reduce the end points of the line to reference (ground) stations. These are combined in the following expression:

$$\text{Corr.} + \frac{S}{24R}\left[\frac{S^2}{R} - 12(h'_1 + h'_2)\right]$$



SAMPLE RUNS

```
EDM SL RECIP VER ANG
FORMAT AS FOLLOWS:

ANG D.MS/LINEAR MTRS
LAT N+ S-/AZ 0 DEG N

INPUT DATA IN ORDER:

LAT/ AZI/ VA 1/VA 2:

        30.
       100.
   -2.00012
    1.50006

  T1/  D2/  T2/  D1:

     10.01
      1.53
      1.65
     10.21
```

```
SLOPE DIS/ EL STA 1:

  30123.456
   2110.878

EDME: H1/H2 ABV STA

     10.32
       1.7

DEL H
     -999.122     MTRS

H2
     1111.756     MTRS

DIST     SL
   30098.997      MTRS

NEXT?

LAT/ AZI/ VA 1/VA 2:
```

PROGRAM LISTING

000	01	1	050	02	2	100	98	ADV	150	07	7
001	07	7	051	01	1	101	01	1	151	01	1
002	01	1	052	03	3	102	03	3	152	03	3
003	06	6	053	02	2	103	03	3	153	03	3
004	03	3	054	03	3	104	01	1	154	07	7
005	00	0	055	05	5	105	02	2	155	00	0
006	00	0	056	03	3	106	02	2	156	00	0
007	00	0	057	00	0	107	00	0	157	03	3
008	03	3	058	01	1	108	00	0	158	01	1
009	06	6	059	03	3	109	01	1	159	69	OP
010	69	OP	060	69	OP	110	06	6	160	01	01
011	01	01	061	01	01	111	69	OP	161	04	4
012	02	2	062	03	3	112	01	01	162	07	7
013	07	7	063	07	7	113	04	4	163	00	0
014	00	0	064	00	0	114	00	0	164	00	0
015	00	0	065	00	0	115	03	3	165	03	3
016	03	3	066	01	1	116	00	0	166	06	6
017	05	5	067	03	3	117	03	3	167	02	2
018	01	1	068	03	3	118	06	6	168	00	0
019	07	7	069	06	6	119	06	6	169	06	6
020	01	1	070	00	0	120	03	3	170	03	3
021	05	5	071	00	0	121	02	2	171	69	OP
022	69	OP	072	69	OP	122	07	7	172	02	02
023	02	02	073	02	02	123	69	OP	173	01	1
024	02	2	074	02	2	124	02	02	174	03	3
025	04	4	075	01	1	125	02	2	175	04	4
026	03	3	076	03	3	126	04	4	176	06	6
027	03	3	077	02	2	127	03	3	177	00	0
028	00	0	078	02	2	128	01	1	178	00	0
029	00	0	079	07	7	129	01	1	179	00	0
030	04	4	080	02	2	130	07	7	180	01	1
031	02	2	081	07	7	131	01	1	181	00	0
032	01	1	082	03	3	132	03	3	182	00	0
033	07	7	083	04	4	133	03	3	183	69	OP
034	69	OP	084	69	OP	134	05	5	184	03	03
035	03	03	085	03	03	135	69	OP	185	01	1
036	03	3	086	04	4	136	03	03	186	06	6
037	05	5	087	03	3	137	03	3	187	01	1
038	00	0	088	03	3	138	00	0	188	07	7
039	00	0	089	06	6	139	03	3	189	02	2
040	01	1	090	06	6	140	07	7	190	02	2
041	03	3	091	02	2	141	03	3	191	00	0
042	03	3	092	00	0	142	05	5	192	00	0
043	01	1	093	00	0	143	03	3	193	03	3
044	02	2	094	00	0	144	06	6	194	01	1
045	02	2	095	00	0	145	69	OP	195	69	OP
046	69	OP	096	69	OP	146	04	04	196	04	04
047	04	04	097	04	04	147	69	OP	197	69	OP
048	69	OP	098	69	OP	148	05	05	198	05	05
049	05	05	099	05	05	149	02	2	199	98	ADV

200	02	2
201	04	4
202	03	3
203	01	1
204	03	3
205	03	3
206	04	4
207	01	1
208	03	3
209	07	7
210	69	DP
211	01	01
212	01	1
213	06	6
214	01	1
215	03	3
216	03	3
217	07	7
218	01	1
219	03	3
220	69	DP
221	02	02
222	02	2
223	04	4
224	03	3
225	01	1
226	00	0
227	00	0
228	03	3
229	02	2
230	69	DP
231	03	03
232	03	3
233	05	5
234	01	1
235	06	6
236	01	1
237	07	7
238	03	3
239	05	5
240	06	6
241	02	2
242	69	DP
243	04	04
244	69	DP
245	05	05
246	98	ADV
247	76	LBL
248	87	IFF
249	02	2
250	07	7
251	01	1
252	03	3
253	03	3
254	07	7
255	06	6
256	03	3
257	00	0
258	00	0
259	69	DP
260	01	01
261	01	1
262	03	3
263	04	4
264	06	6
265	02	2
266	04	4
267	06	6
268	03	3
269	00	0
270	00	0
271	69	DP
272	02	02
273	04	4
274	02	2
275	01	1
276	03	3
277	00	0
278	00	0
279	00	0
280	02	2
281	06	6
282	03	3
283	69	DP
284	03	03
285	04	4
286	02	2
287	01	1
288	03	3
289	00	0
290	00	0
291	00	0
292	03	3
293	06	6
294	02	2
295	69	DP
296	04	04
297	69	DP
298	05	05
299	98	ADV
300	98	ADV
301	98	ADV
302	91	R/S
303	99	PRT
304	42	STO
305	09	09
306	91	R/S
307	99	PRT
308	42	STO
309	10	10
310	91	R/S
311	99	PRT
312	42	STO
313	11	11
314	91	R/S
315	99	PRT
316	42	STO
317	12	12
318	98	ADV
319	69	DP
320	00	00
321	03	3
322	07	7
323	00	0
324	02	2
325	06	6
326	03	3
327	69	DP
328	01	01
329	03	3
330	02	2
331	00	0
332	03	3
333	06	6
334	03	3
335	69	DP
336	02	02
337	03	3
338	07	7
339	00	0
340	03	3
341	06	6
342	03	3
343	69	DP
344	03	03
345	03	3
346	02	2
347	00	0
348	02	2
349	06	6
350	02	2
351	69	DP
352	04	04
353	69	DP
354	05	05
355	98	ADV
356	98	ADV
357	98	ADV
358	91	R/S
359	99	PRT
360	75	-
361	91	R/S
362	99	PRT
363	75	-
364	91	R/S
365	99	PRT
366	85	+
367	91	R/S
368	99	PRT
369	95	=
370	42	STO
371	03	03
372	98	ADV
373	03	3
374	06	6
375	02	2
376	07	7
377	03	3
378	02	2
379	03	3
380	03	3
381	01	1
382	07	7
383	69	DP
384	01	01
385	01	1
386	06	6
387	02	2
388	04	4
389	03	3
390	06	6
391	06	6
392	03	3
393	69	DP
394	02	02
395	01	1
396	07	7
397	02	2
398	07	7
399	00	0

400	00	0	450	00	0	500	11	11	550	01	1
401	03	3	451	02	2	501	19	D'	551	95	=
402	06	6	452	06	6	502	75	-	552	65	×
403	69	OP	453	03	3	503	53	(	553	06	6
404	03	03	454	02	2	504	43	RCL	554	04	4
405	03	3	455	03	3	505	12	12	555	00	0
406	07	7	456	69	OP	506	19	D'	556	00	0
407	01	1	457	02	02	507	85	+	557	00	0
408	03	3	458	03	3	508	43	RCL	558	00	0
409	00	0	459	00	0	509	03	03	559	00	0
410	00	0	460	00	0	510	95	=	560	95	=
411	00	0	461	01	1	511	55	÷	561	42	STO
412	02	2	462	03	3	512	02	2	562	01	01
413	06	6	463	01	1	513	95	=	563	43	RCL
414	02	2	464	04	4	514	38	SIN	564	04	04
415	69	OP	465	04	4	515	65	×	565	33	X^2
416	04	04	466	02	2	516	43	RCL	566	75	-
417	69	OP	467	69	OP	517	04	04	567	43	RCL
418	05	05	468	03	03	518	95	=	568	02	02
419	98	ADV	469	03	3	519	42	STO	569	33	X^2
420	98	ADV	470	06	6	520	02	02	570	95	=
421	98	ADV	471	03	3	521	44	SUM	571	55	÷
422	91	R/S	472	07	7	522	14	14	572	53	(
423	99	PRT	473	01	1	523	53	(	573	01	1
424	42	STO	474	03	3	524	43	RCL	574	85	+
425	04	04	475	00	0	525	09	09	575	53	(
426	22	INV	476	00	0	526	19	D'	576	43	RCL
427	49	PRD	477	69	OP	527	39	COS	577	14	14
428	03	03	478	04	04	528	33	X^2	578	85	+
429	91	R/S	479	69	OP	529	55	÷	579	43	RCL
430	99	PRT	480	05	05	530	02	2	580	05	05
431	42	STO	481	98	ADV	531	09	9	581	54	)
432	14	14	482	98	ADV	532	05	5	582	55	÷
433	42	STO	483	98	ADV	533	95	=	583	43	RCL
434	05	05	484	91	R/S	534	65	×	584	01	01
435	98	ADV	485	99	PRT	535	53	(	585	54	)
436	01	1	486	42	STO	536	01	1	586	95	=
437	07	7	487	06	06	537	85	+	587	34	FX
438	01	1	488	94	+/-	538	02	2	588	75	-
439	06	6	489	85	+	539	65	×	589	24	CE
440	03	3	490	91	R/S	540	53	(	590	35	1/X
441	00	0	491	99	PRT	541	43	RCL	591	65	×
442	01	1	492	44	SUM	542	10	10	592	43	RCL
443	07	7	493	06	06	543	19	D'	593	07	07
444	06	6	494	95	=	544	39	COS	594	65	×
445	02	2	495	42	STO	545	33	X^2	595	53	(
446	69	OP	496	07	07	546	54	)	596	43	RCL
447	01	01	497	98	ADV	547	95	=	597	02	02
448	02	2	498	53	(	548	94	+/-	598	85	+
449	03	3	499	43	RCL	549	85	+	599	43	RCL

600	07	07	650	17	B'	700	01	1	750	55	÷
601	55	÷	651	43	RCL	701	07	7	751	43	RCL
602	02	2	652	02	02	702	04	4	752	01	01
603	54	)	653	18	C'	703	04	4	753	75	-
604	95	=	654	02	2	704	03	3	754	01	1
605	42	STO	655	03	3	705	07	7	755	02	2
606	08	08	656	00	0	706	07	7	756	65	×
607	75	-	657	03	3	707	01	1	757	43	RCL
608	01	1	658	00	0	708	69	OP	758	06	06
609	00	0	659	00	0	709	01	01	759	54	)
610	00	0	660	00	0	710	69	OP	760	95	=
611	00	0	661	00	0	711	05	05	761	44	SUM
612	00	0	662	00	0	712	98	ADV	762	08	08
613	95	=	663	00	0	713	61	GTO	763	61	GTO
614	77	GE	664	69	OP	714	87	IFF	764	88	DMS
615	16	A'	665	01	01	715	76	LBL	765	76	LBL
616	43	RCL	666	69	OP	716	11	A	766	17	B'
617	15	15	667	05	05	717	22	INV	767	03	3
618	75	-	668	17	B'	718	58	FIX	768	00	0
619	02	2	669	43	RCL	719	47	CMS	769	03	3
620	95	=	670	14	14	720	25	CLR	770	07	7
621	77	GE	671	18	C'	721	70	RAD	771	03	3
622	16	A'	672	01	1	722	98	ADV	772	05	5
623	43	RCL	673	06	6	723	81	RST	773	03	3
624	16	16	674	02	2	724	76	LBL	774	06	6
625	75	-	675	04	4	725	19	D'	775	69	OP
626	02	2	676	03	3	726	88	DMS	776	04	04
627	95	=	677	06	6	727	65	×	777	92	RTN
628	77	GE	678	03	3	728	89	π	778	76	LBL
629	16	A'	679	07	7	729	55	÷	779	18	C'
630	76	LBL	680	00	0	730	01	1	780	58	FIX
631	88	DMS	681	00	0	731	08	8	781	03	03
632	98	ADV	682	69	OP	732	00	0	782	69	OP
633	98	ADV	683	01	01	733	54	)	783	06	06
634	69	OP	684	03	3	734	92	RTN	784	98	ADV
635	00	00	685	06	6	735	76	LBL	785	22	INV
636	01	1	686	02	2	736	16	A'	786	58	FIX
637	06	6	687	07	7	737	43	RCL	787	69	OP
638	01	1	688	69	OP	738	08	08	788	00	00
639	07	7	689	02	02	739	55	÷	789	92	RTN
640	02	2	690	69	OP	740	43	RCL	790	00	0
641	07	7	691	05	05	741	01	01	791	00	0
642	00	0	692	17	B'	742	55	÷	792	00	0
643	00	0	693	43	RCL	743	02	2	793	00	0
644	02	2	694	08	08	744	04	4	794	00	0
645	03	3	695	18	C'	745	65	×	795	00	0
646	69	OP	696	98	ADV	746	53	(	796	00	0
647	01	01	697	98	ADV	747	43	RCL	797	00	0
648	69	OP	698	03	3	748	08	08	798	00	0
649	05	05	699	01	1	749	33	X^2	799	00	0

APPENDIX E

THREE POINT (RESECTION) PROBLEM

Purpose: Reference TM 5-237, Surveying Computer's Manual, 1964 Pages 230/1 Paragraph 81.

This program will solve the unknown pearameters of a quadrilateral when three of the stations have known coordinates and horizontal directions are observed to them from the unknown station.

This solution is not to be confused with the inaccessible base or special angle problems.

NOTES:

1. The program is designed for use with the TI Printer (PC-100 Series).
2. The input values of the sides must be metric due to metric constants generated within the program.
3. Each of the two angular values, at the unknown (occupied) station between pairs of the three unknown stations, is input as one numerical entry with a decimal point between the degrees and minutes values.

INSTRUCTIONS:

1. Printer "ON" and, then, Calculator "ON".
2. Load the two sides of the magnetic cards:
   a. CLR, RST, 1, 2nd, CP, 17, 1, INV, 2nd, WRITE; Enter Side 1.
   b. 2; Enter Side 2.

Note: The underlined numbers may be replaced by zeroes. Refer to the operating instruction manual if further difficulty occurs.

3. Depress "A" for initialization and input.

4. Upon completion of the X, Y computation, another resection problem can be entered or: Depress "B" for the remaining parts of the figure.

INPUT DATA:

1. Side a, in meters.

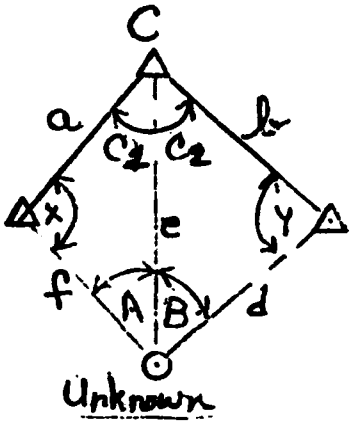
2. Side b, in meters.

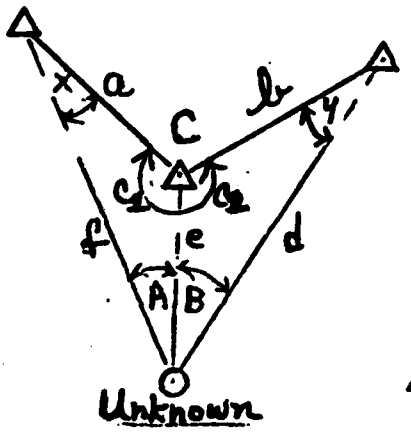
3. Angle A at the unknown station which is opposite side a.

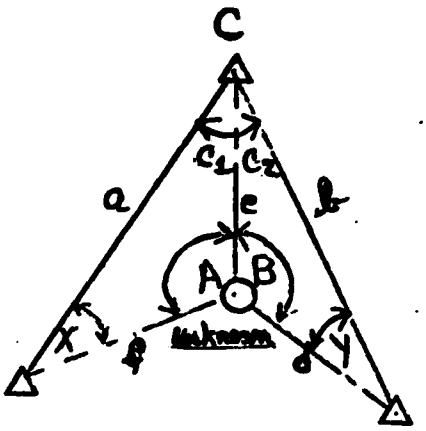
4. Angle B at the unknown station which is opposite side b.

5. Angle C at the known station (opposite the unknown station in the quadrilateral — the middle one of three knowns).

FORMULATION and COMPUTATION:







$$1/2\ (x+y) = 180^\circ - 1/2\ (A+B+C)$$

$$\text{Tan } z = \frac{b \sin A}{a \sin B}$$

$$\text{Tan } \frac{(x-y)}{2} = \text{Tan } \frac{(x+y)}{2} \text{ Tan } (z - 45^\circ)$$

$$x = \frac{(x+y)}{2} + \frac{(x-y)}{2},\quad y = \frac{(x+y)}{2} - \frac{(x-y)}{2}$$

SAMPLE RUNS

```
RESECTION:      INPUT

SIDES:A, B/ANGS:A, B, C


 4870.241
 9477.507

  30.41597
  64.27113
 108.09343

 91.285506        =X
 65.121964        =Y

NEXT:A, B/ANGS:   B?


 57.490534        =C1
 50.202924        =C2

 8087.012         =D
 8073.751         =E
 9536.170         =F

RESECTION:      INPUT

SIDES:A, B/ANGS:A, B, C
```

000	25	CLR	050	05	05	100	43	RCL	150	05	5
001	98	ADV	051	65	×	101	02	02	151	01	1
002	98	ADV	052	43	RCL	102	58	FIX	152	07	7
003	98	ADV	053	08	08	103	06	06	153	03	3
004	91	R/S	054	88	DMS	104	98	ADV	154	06	6
005	42	STO	055	38	SIN	105	69	OP	155	01	1
006	04	04	056	55	÷	106	06	06	156	07	7
007	99	PRT	057	43	RCL	107	22	INV	157	01	1
008	91	R/S	058	04	04	108	58	FIX	158	05	5
009	42	STO	059	55	÷	109	06	6	159	69	OP
010	05	05	060	43	RCL	110	04	4	160	01	01
011	99	PRT	061	09	09	111	04	4	161	03	3
012	98	ADV	062	88	DMS	112	05	5	162	07	7
013	91	R/S	063	38	SIN	113	69	OP	163	02	2
014	42	STO	064	54	)	114	04	04	164	04	4
015	08	08	065	22	INV	115	43	RCL	165	03	3
016	99	PRT	066	30	TAN	116	01	01	166	02	2
017	91	R/S	067	75	-	117	58	FIX	167	03	3
018	42	STO	068	04	4	118	06	06	168	01	1
019	09	09	069	05	5	119	69	OP	169	06	6
020	99	PRT	070	54	)	120	06	06	170	02	2
021	91	R/S	071	30	TAN	121	22	INV	171	69	OP
022	99	PRT	072	95	=	122	58	FIX	172	02	02
023	88	DMS	073	22	INV	123	03	3	173	02	2
024	85	+	074	30	TAN	124	01	1	174	04	4
025	43	RCL	075	44	SUM	125	01	1	175	03	3
026	08	08	076	06	06	126	07	7	176	01	1
027	88	DMS	077	75	-	127	05	5	177	03	3
028	85	+	078	43	RCL	128	00	0	178	03	3
029	43	RCL	079	07	07	129	03	3	179	04	4
030	09	09	080	95	=	130	07	7	180	01	1
031	88	DMS	081	94	+/-	131	69	OP	181	03	3
032	95	=	082	42	STO	132	01	01	182	07	7
033	55	÷	083	07	07	133	01	1	183	69	OP
034	02	2	084	22	INV	134	04	4	184	04	04
035	75	-	085	88	DMS	135	07	7	185	98	ADV
036	01	1	086	42	STO	136	01	1	186	69	OP
037	08	8	087	01	01	137	69	OP	187	05	05
038	00	0	088	43	RCL	138	04	04	188	03	3
039	95	=	089	06	06	139	98	ADV	189	06	6
040	94	+/-	090	22	INV	140	69	OP	190	02	2
041	42	STO	091	88	DMS	141	05	05	191	04	4
042	06	06	092	42	STO	142	81	RST	192	01	1
043	42	STO	093	02	02	143	76	LBL	193	06	6
044	07	07	094	06	6	144	11	A	194	01	1
045	30	TAN	095	04	4	145	22	INV	195	07	7
046	65	×	096	04	4	146	58	FIX	196	03	3
047	53	(	097	04	4	147	69	OP	197	06	6
048	53	(	098	69	OP	148	00	00	198	69	OP
049	43	RCL	099	04	04	149	03	3	199	01	01

200	06	6	250	75	-	300	65	×	350	05	05
201	02	2	251	43	RCL	301	43	RCL	351	43	RCL
202	01	1	252	06	06	302	04	04	352	04	04
203	03	3	253	95	=	303	33	X^2	353	65	×
204	05	5	254	42	STO	304	65	×	354	43	RCL
205	07	7	255	03	03	305	43	RCL	355	06	06
206	01	1	256	01	1	306	06	06	356	38	SIN
207	04	4	257	08	8	307	38	SIN	357	55	÷
208	06	6	258	00	0	308	55	÷	358	43	RCL
209	03	3	259	75	-	309	43	RCL	359	08	08
210	69	DP	260	43	RCL	310	08	08	360	38	SIN
211	02	02	261	09	09	311	38	SIN	361	95	=
212	01	1	262	88	DMS	312	55	÷	362	42	STO
213	03	3	263	42	STO	313	01	1	363	04	04
214	03	3	264	09	09	314	04	4	364	43	RCL
215	01	1	265	75	-	315	01	1	365	01	01
216	02	2	266	43	RCL	316	04	4	366	22	INV
217	02	2	267	07	07	317	08	8	367	88	DMS
218	03	3	268	95	=	318	52	EE	368	42	STO
219	06	6	269	42	STO	319	08	8	369	01	01
220	06	6	270	01	01	320	95	=	370	43	RCL
221	02	2	271	38	SIN	321	22	INV	371	03	03
222	69	DP	272	65	×	322	52	EE	372	22	INV
223	03	03	273	43	RCL	323	44	SUM	373	88	DMS
224	01	1	274	05	05	324	03	03	374	42	STO
225	03	3	275	33	X^2	325	43	RCL	375	03	03
226	05	5	276	65	×	326	01	01	376	22	INV
227	07	7	277	43	RCL	327	38	SIN	377	58	FIX
228	01	1	278	07	07	328	65	×	378	06	6
229	04	4	279	38	SIN	329	43	RCL	379	04	4
230	05	5	280	55	÷	330	05	05	380	01	1
231	07	7	281	43	RCL	331	55	÷	381	05	5
232	01	1	282	09	09	332	43	RCL	382	00	0
233	05	5	283	38	SIN	333	09	09	383	02	2
234	69	DP	284	55	÷	334	38	SIN	384	69	DP
235	04	04	285	01	1	335	95	=	385	04	04
236	98	ADV	286	04	4	336	42	STO	386	43	RCL
237	69	DP	287	01	1	337	02	02	387	03	03
238	05	05	288	04	4	338	43	RCL	388	58	FIX
239	81	RST	289	08	8	339	03	03	389	06	06
240	25	CLR	290	52	EE	340	38	SIN	390	98	ADV
241	01	1	291	08	8	341	65	×	391	69	DP
242	08	8	292	95	=	342	43	RCL	392	06	06
243	00	0	293	22	INV	343	04	04	393	22	INV
244	75	-	294	52	EE	344	55	÷	394	58	FIX
245	43	RCL	295	44	SUM	345	43	RCL	395	06	6
246	08	08	296	01	01	346	08	08	396	04	4
247	88	DMS	297	43	RCL	347	38	SIN	397	01	1
248	42	STO	298	03	03	348	95	=	398	05	5
249	08	08	299	38	SIN	349	42	STO	399	00	0

400	03	3	450	69	DP
401	69	DP	451	06	06
402	04	04	452	22	INV
403	43	RCL	453	58	FIX
404	01	01	454	11	A
405	58	FIX	455	76	LBL
406	06	06	456	12	B
407	69	DP	457	22	INV
408	06	06	458	58	FIX
409	22	INV	459	69	DP
410	58	FIX	460	00	00
411	06	6	461	61	GTO
412	04	4	462	02	02
413	01	1	463	40	40
414	06	6	464	00	0
415	69	DP	465	00	0
416	04	04	466	00	0
417	43	RCL	467	00	0
418	02	02	468	00	0
419	58	FIX	469	00	0
420	03	03	470	00	0
421	98	ADV	471	00	0
422	69	DP	472	00	0
423	06	06	473	00	0
424	22	INV	474	00	0
425	58	FIX	475	00	0
426	06	6	476	00	0
427	04	4	477	00	0
428	01	1	478	00	0
429	07	7	479	00	0
430	69	DP			
431	04	04			
432	43	RCL			
433	05	05			
434	58	FIX			
435	03	03			
436	69	DP			
437	06	06			
438	22	INV			
439	58	FIX			
440	06	6			
441	04	4			
442	02	2			
443	01	1			
444	69	DP			
445	04	04			
446	43	RCL			
447	04	04			
448	58	FIX			
449	03	03			

APPENDIX F

TRANSFORMATION OF GEODETIC COORDINATES (NORTH AMERICAN DATUM 1927) TO STATE PLANE COORDINATES (LAMERT PROJECTION)

Purpose: Reference TM 5-237, Surveying Computer's Manual, 1964 Page 366, Paragraphs 179/180.

The Lambert Conical Conformal type of projection is used with one or two standard parallels in areas extending mainly in an east-west direction. The projection provides very simple formulas for the conversion of geodetic to grid coordinates using the included constants. This projection is used for many states by the National Geodetic Survey (NGS) for the state plane grid systems in the United States.

NOTES:

1. This program is designed to be used with the TI Printer (PC-100 Series).
2. The listed program is written using the constants necessary to convert geodetic coordinates (North American Datum 1927) to state plan coordinates (Lambert Projection, California, Zone V).
3. The program listing/instructions can be modified for storage on magnetic cards for specific states or the constants can be input after initialising and depressing "E". See the attached listing of state/zone constants and codes.

INSTRUCTIONS:

1. Printer "ON" and, then, Calculator "ON".

2. Load the three sides of the magnetic cards:

   a. CLR, RST, 2, 2nd, CP, 17, 1, INV, 2nd, WRITE; Enter Side 1.

   b. 2; Enter Side 2.

   c. 3; Enter Side 3.

Note: The numbers which are underlined may be replaced by zeroes. Refer to operating instruction manual if difficulty occurs.

3. Depress "A" for initialization and:

   a. State, Zone, Geod/Grid.

   b. Constants, Storage Registers.

   c. Instructions for input of new constants and/or coordinates.

4. Output includes the "x" and "y" values and the mapping angle (or convergence angle) for use with known azimuths at the station.

INPUT DATA:

1. New constants, L1 through L11 (See attached listings).

2. Latitude: N (+), S(-).

3. Longitude: W(+), E(-).

FORMULATION and COMPUTATION:

1. Computations are performed in radians.

2. The equations used are from C & GS Publication 62-4 as modified by T. Vincenty for use in small calculators.

$$\sigma = (\omega_o - \phi + B \sin \phi \cos \phi (1 - C \cos^2 \phi (1 - D \cos^2 \phi)))/(A)$$

where: $A = 1.005104574$
$1/B = 195.90275$
$1/C = 234.8457$
$1/D = 190.62$

$$\beta = \sigma (1 + E \sigma^2 (1 + F \sigma (G \sigma - 1)))$$

where: E, F, and G are from C & GS Pub 62-4 values of L_9, L_{10}, and L_{11} as follows:

$$E = L_9 c^2 10^{-16} \qquad F = L_{10} c 10^{-8}/L_9 \qquad G = L_{11} c 10^{-8}/L_{10}$$

$$R = R_o + cm\beta \qquad \theta = (\lambda_o - \lambda) \sin \phi_o$$

$$x = x_o + R \sin \theta$$

$$y = R_1 - R + 2 R \sin^2 (\theta / 2)$$

SAMPLE RUNS

```
CA 4.5 LAM GEOD/GRID

     2000000.       09
        7080.       10
 14.38132943        11
 30649424.27        12
 2099537.853        13
 .5700119219        14
 6.041365233        15
   594.51692        16
    57.39339        17
        999.        18
        0.91        19

E:NEW CONSTANTS   OR

INPUT LATITUDE, THEN
LONGITUDE DEG.MINSEC



 34.59365366
 16.59540661

 2300000.010      =X

  545000.001      =Y

MAP ANGLE

          0.      DEG
         34.      MIN
    15.42531      SEC

ANOTHER?
INPUT LATITUDE, THEN
LONGITUDE DEG.MINSEC
```

PROGRAM LISTING

```
000  98 ADV     050  08  8      100  03  3      150  69 DP
001  98 ADV     051  05  5      101  09  9      151  03  03
002  02  2      052  03  3      102  42 STO     152  06  6
003  52 EE      053  42 STO     103  17  17     153  03  3
004  06  6      054  13  13     104  09  9      154  02  2
005  22 INV     055  93  .      105  09  9      155  02  2
006  52 EE      056  05  5      106  09  9      156  03  3
007  42 STO     057  07  7      107  42 STO     157  05  5
008  09  09     058  00  0      108  18  18     158  02  2
009  07  7      059  00  0      109  93  .      159  04  4
010  00  0      060  01  1      110  09  9      160  01  1
011  08  8      061  01  1      111  01  1      161  06  6
012  00  0      062  09  9      112  42 STO     162  69 DP
013  42 STO     063  02  2      113  19  19     163  04  04
014  10  10     064  01  1      114  22 INV     164  69 DP
015  01  1      065  09  9      115  58 FIX     165  05  05
016  04  4      066  42 STO     116  69 DP      166  98 ADV
017  93  .      067  14  14     117  00  00     167  09  9
018  03  3      068  06  6      118  01  1      168  22 INV
019  08  8      069  93  .      119  05  5      169  90 LST
020  01  1      070  00  0      120  01  1      170  98 ADV
021  03  3      071  04  4      121  03  3      171  01  1
022  02  2      072  01  1      122  00  0      172  07  7
023  09  9      073  03  3      123  00  0      173  06  6
024  04  4      074  06  6      124  00  0      174  02  2
025  03  3      075  05  5      125  05  5      175  03  3
026  09  9      076  02  2      126  04  4      176  01  1
027  42 STO     077  03  3      127  00  0      177  01  1
028  11  11     078  03  3      128  69 DP      178  07  7
029  03  3      079  08  8      129  01  01     179  04  4
030  00  0      080  09  9      130  00  0      180  03  3
031  06  6      081  42 STO     131  06  6      181  69 DP
032  04  4      082  15  15     132  00  0      182  01  01
033  09  9      083  05  5      133  00  0      183  01  1
034  04  4      084  09  9      134  02  2      184  05  5
035  02  2      085  04  4      135  07  7      185  03  3
036  04  4      086  93  .      136  01  1      186  02  2
037  93  .      087  05  5      137  03  3      187  03  3
038  02  2      088  01  1      138  03  3      188  01  1
039  07  7      089  06  6      139  00  0      189  03  3
040  42 STO     090  09  9      140  69 DP      190  06  6
041  12  12     091  02  2      141  02  02     191  69 DP
042  02  2      092  42 STO     142  02  2      192  02  02
043  00  0      093  16  16     143  02  2      193  03  3
044  09  9      094  05  5      144  01  1      194  07  7
045  09  9      095  07  7      145  07  7      195  01  1
046  05  5      096  93  .      146  03  3      196  03  3
047  03  3      097  03  3      147  02  2      197  03  3
048  07  7      098  09  9      148  01  1      198  01  1
049  93  .      099  03  3      149  06  6      199  03  3
```

200	07	7	250	03	3	300	03	3	350	06	6
201	03	3	251	07	7	301	01	1	351	02	2
202	06	6	252	02	2	302	03	3	352	94	+/-
203	69	OP	253	03	3	303	06	6	353	85	+
204	03	03	254	01	1	304	01	1	354	01	1
205	03	3	255	07	7	305	07	7	355	95	=
206	02	2	256	03	3	306	01	1	356	65	×
207	03	3	257	01	1	307	05	5	357	18	C'
208	05	5	258	69	OP	308	69	OP	358	39	COS
209	69	OP	259	04	04	309	04	04	359	33	X^2
210	04	04	260	69	OP	310	69	OP	360	55	÷
211	69	OP	261	05	05	311	05	05	361	02	2
212	05	05	262	02	2	312	98	ADV	362	03	3
213	98	ADV	263	07	7	313	98	ADV	363	04	4
214	76	LBL	264	03	3	314	98	ADV	364	93	.
215	38	SIN	265	02	2	315	25	CLR	365	08	8
216	02	2	266	03	3	316	91	R/S	366	04	4
217	04	4	267	01	1	317	99	PRT	367	05	5
218	03	3	268	02	2	318	42	STO	368	07	7
219	01	1	269	02	2	319	02	02	369	94	+/-
220	03	3	270	02	2	320	91	R/S	370	85	+
221	03	3	271	04	4	321	99	PRT	371	01	1
222	04	4	272	69	OP	322	17	B'	372	95	=
223	01	1	273	01	01	323	94	+/-	373	65	×
224	03	3	274	03	3	324	42	STO	374	18	C'
225	07	7	275	07	7	325	03	03	375	38	SIN
226	69	OP	276	04	4	326	43	RCL	376	65	×
227	01	01	277	01	1	327	10	10	377	18	C'
228	02	2	278	01	1	328	55	÷	378	39	COS
229	07	7	279	06	6	329	06	6	379	55	÷
230	01	1	280	01	1	330	00	0	380	01	1
231	03	3	281	07	7	331	95	=	381	09	9
232	03	3	282	00	0	332	17	B'	382	05	5
233	07	7	283	00	0	333	44	SUM	383	93	.
234	02	2	284	69	OP	334	03	03	384	09	9
235	04	4	285	02	02	335	43	RCL	385	00	0
236	69	OP	286	01	1	336	14	14	386	02	2
237	02	02	287	06	6	337	49	PRD	387	07	7
238	03	3	288	01	1	338	03	03	388	05	5
239	07	7	289	07	7	339	18	C'	389	75	-
240	04	4	290	02	2	340	17	B'	390	18	C'
241	01	1	291	02	2	341	42	STO	391	85	+
242	01	1	292	04	4	342	02	02	392	43	RCL
243	06	6	293	00	0	343	39	COS	393	15	15
244	01	1	294	03	3	344	33	X^2	394	19	D'
245	07	7	295	00	0	345	55	÷	395	35	1/X
246	05	5	296	69	OP	346	01	1	396	95	=
247	07	7	297	03	03	347	09	9	397	55	+
248	69	OP	298	02	2	348	00	0	398	01	1
249	03	03	299	04	4	349	93	.	399	93	.

400	00	0	450	13	13	500	06	6	550	00	0
401	00	0	451	95	=	501	04	4	551	55	÷
402	05	5	452	42	STO	502	04	4	552	89	π
403	01	1	453	02	02	503	05	5	553	95	=
404	00	0	454	65	×	504	00	0	554	22	INV
405	04	4	455	43	RCL	505	00	0	555	88	DMS
406	05	5	456	03	03	506	69	DP	556	42	STO
407	07	7	457	38	SIN	507	04	04	557	03	03
408	04	4	458	85	+	508	18	C'	558	01	1
409	95	=	459	43	RCL	509	58	FIX	559	06	6
410	42	STO	460	09	09	510	03	03	560	01	1
411	02	02	461	95	=	511	98	ADV	561	07	7
412	19	D'	462	42	STO	512	69	DP	562	02	2
413	55	÷	463	04	04	513	06	06	563	02	2
414	43	RCL	464	06	6	514	22	INV	564	69	DP
415	18	18	465	04	4	515	58	FIX	565	04	04
416	75	-	466	04	4	516	69	DP	566	43	RCL
417	01	1	467	04	4	517	00	00	567	03	03
418	95	=	468	00	0	518	03	3	568	59	INT
419	65	×	469	00	0	519	00	0	569	22	INV
420	18	C'	470	69	DP	520	01	1	570	44	SUM
421	19	D'	471	04	04	521	03	3	571	03	03
422	55	÷	472	43	RCL	522	03	3	572	98	ADV
423	43	RCL	473	04	04	523	03	3	573	69	DP
424	17	17	474	98	ADV	524	00	0	574	06	06
425	85	+	475	58	FIX	525	00	0	575	03	3
426	01	1	476	03	03	526	01	1	576	00	0
427	95	=	477	69	DP	527	03	3	577	02	2
428	65	×	478	06	06	528	69	DP	578	04	4
429	18	C'	479	22	INV	529	01	01	579	03	3
430	33	X^2	480	58	FIX	530	03	3	580	01	1
431	19	D'	481	43	RCL	531	01	1	581	69	DP
432	19	D'	482	03	03	532	02	2	582	04	04
433	55	÷	483	55	÷	533	02	2	583	43	RCL
434	43	RCL	484	02	2	534	02	2	584	03	03
435	16	16	485	95	=	535	07	7	585	19	D'
436	85	+	486	38	SIN	536	01	1	586	19	D'
437	01	1	487	33	X^2	537	07	7	587	95	=
438	95	=	488	65	×	538	00	0	588	42	STO
439	65	×	489	18	C'	539	00	0	589	03	03
440	18	C'	490	65	×	540	69	DP	590	59	INT
441	65	×	491	02	2	541	02	02	591	22	INV
442	43	RCL	492	75	-	542	98	ADV	592	44	SUM
443	13	13	493	18	C'	543	69	DP	593	03	03
444	19	D'	494	85	+	544	05	05	594	69	DP
445	85	+	495	43	RCL	545	43	RCL	595	06	06
446	43	RCL	496	12	12	546	03	03	596	03	3
447	11	11	497	95	=	547	65	×	597	06	6
448	65	×	498	42	STO	548	01	1	598	01	1
449	43	RCL	499	02	02	549	08	8	599	07	7

```
600  01   1
601  05   5
602  69  DP
603  04   04
604  43  RCL
605  03   03
606  19  D'
607  19  D'
608  95   =
609  58  FIX
610  05   05
611  69  DP
612  06   06
613  22  INV
614  58  FIX
615  69  DP
616  00   00
617  01   1
618  03   3
619  03   3
620  01   1
621  03   3
622  02   2
623  03   3
624  07   7
625  02   2
626  03   3
627  69  DP
628  01   01
629  01   1
630  07   7
631  03   3
632  05   5
633  07   7
634  01   1
635  00   0
636  00   0
637  00   0
638  00   0
639  69  DP
640  02   02
641  98  ADV
642  69  DP
643  05   05
644  61  GTO
645  38  SIN
646  76  LBL
647  18  C'
648  43  RCL
649  02   02
650  92  RTN
651  76  LBL
652  19  D'
653  65   ×
654  01   1
655  00   0
656  92  RTN
657  76  LBL
658  17  B'
659  88  DMS
660  75   -
661  01   1
662  00   0
663  00   0
664  95   =
665  77   GE
666  34  FX
667  85   +
668  01   1
669  00   0
670  00   0
671  95   =
672  76  LBL
673  34  FX
674  65   ×
675  89   π
676  55   ÷
677  01   1
678  08   8
679  00   0
680  95   =
681  92  RTN
682  76  LBL
683  15   E
684  09   9
685  42  STO
686  00   00
687  01   1
688  01   1
689  42  STO
690  01   01
691  76  LBL
692  33  X²
693  43  RCL
694  00   00
695  98  ADV
696  99  PRT
697  75   -
698  08   8
699  95   =
700  91  R/S
701  99  PRT
702  72  ST*
703  00   00
704  69  DP
705  20   20
706  97  DSZ
707  01   01
708  33  X²
709  61  GTO
710  38  SIN
711  92  RTN
712  76  LBL
713  11   A
714  70  RAD
715  22  INV
716  58  FIX
717  81  RST
718  00   0
719  00   0
720  25  CLR
721  70  RAD
722  98  ADV
723  81  RST
724  76  LBL
725  19  D'
726  88  DMS
727  65   ×
728  89   π
729  55   ÷
730  01   1
731  08   8
732  00   0
733  54   )
734  92  RTN
735  76  LBL
736  16  A'
737  43  RCL
738  08   08
739  55   ÷
740  43  RCL
741  01   01
742  55   ÷
743  02   2
744  04   4
745  65   ×
746  53   (
747  43  RCL
748  08   08
749  33  X²
750  55   ÷
751  43  RCL
752  01   01
753  75   -
754  01   1
755  02   2
756  65   ×
757  43  RCL
758  06   06
759  54   )
760  95   =
761  44  SUM
762  08   08
763  61  GTO
764  88  DMS
765  76  LBL
766  17  B'
767  03   3
768  00   0
769  03   3
770  07   7
771  03   3
772  05   5
773  03   3
774  06   6
775  69  DP
776  04   04
777  92  RTN
778  76  LBL
779  18  C'
780  58  FIX
781  03   03
782  69  DP
783  06   06
784  98  ADV
785  22  INV
786  58  FIX
787  69  DP
788  00   00
789  92  RTN
790  00   0
791  00   0
792  00   0
793  00   0
794  00   0
795  00   0
796  00   0
797  00   0
798  00   0
799  00   0
```

APPENDIX

Lambert Projection Constants

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
	10	3 000 000	7.5707 74528	2 099 382.342	9.19729 71118	30.58736	-106
Alaska*	50.0	10 560	16 564 628.77	0.79692 23940	597.02694	6.40	
	North	2 000 000	13.9445 87488	2 099 566.849	6.18653 07455	55.65314	0.93
Arkansas	3.1	5 520	29 732 882.87	0.58189 91407	594.62757	999	
	South	2 000 000	14.7718 94984	2 099 530.173	5.91651 81558	58.94981	0.88
Arkansas	3.2	5 520	31 511 724.20	0.55969 06871	594.47485	999	
	I	2 000 000	11.5482 67459	2 099 480.129	7.10187 84606	46.10317	1.13
California	4.1	7 320	24 792 436.23	0.65388 43192	595.34551	999	
	II	2 000 000	12.2865 33640	2 099 522.214	6.79664 27326	49.04553	1.06
California	4.2	7 320	26 312 257.65	0.63046 79732	595.10340	999	
	III	2 000 000	12.8872 57544	2 099 552.659	6.56416 00543	51.43955	1.01
California	4.3	7 230	27 512 992.04	0.61223 20427	594.91922	999	
	IV	2 000 000	13.4228 96887	2 099 576.982	6.36804 49092	53.57406	0.97
California	4.4	7 140	28 652 931.96	0.59658 71443	594.76790	999	
	V	2 000 000	14.3813 29439	2 099 537.853	6.04136 52389	57.39339	0.91
California	4.5	7 080	30 649 424.27	0.57001 19219	594.51692	999	
	VI	2 000 000	15.1678 86218	2 099 605.078	5.79450 10359	60.52780	0.86
California	4.6	6 975	32 271 267.72	0.54951 75982	594.33154	999	
	VII	4 186 692.58	14.7124 42842	2 099 677.289	5.93522 87569	58.71246	0.88
California	4.7	7 100	35 055 396.31	0.56124 32071	594.44057	999	
	North	2 000 000	11.7888 03056	2 099 610.755	6.99996 40610	47.06188	1.11
Colorado	5.1	6 330	25 086 068.20	0.64613 34829	595.26427	999	
	Central	2 000 000	12.2793 79233	2 099 566.796	6.79949 49875	49.01733	1.06
Colorado	5.2	6 330	26 243 052.74	0.63068 95773	595.10497	999	

* In eastern hemisphere use L2 = -11040 and enter longitude as negative east of Greenwich.

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
	South	2 000 000	12.8487 82891	2 099 586.717	6.57864 36904	51.28621	1.01
Colorado	5.3	6 330	27 402 231.82	0.61337 80528	594.93171	999	
		600 000	11.2680 94062	2 099 665.962	8.27090 58758	44.98648	1.16
Connecticut	6.0	4 365	23 914 389.02	0.66305 94147	595.44397	999	
	North	2 000 000	17.1606 79006	2 099 593.089	5.24307 17084	68.46860	0.76
Florida	9.3	5 070	36 454 924.53	0.50252 59000	593.93314	999	
	North	2 000 000	10.8292 50755	2 099 586.652	7.42152 89284	43.23744	1.21
Iowa	14.1	5 610	23 162 461.59	0.67774 45518	595.60346	999	
	South	2 000 000	11.4005 83645	2 099 592.955	7.16567 22121	45.51460	1.15
Iowa	14.2	5 610	24 374 096.67	0.65870 10213	595.39708	999	
	North	2 000 000	12.2141 49149	2 099 610.772	6.82559 35033	48.74582	1.07
Kansas	15.1	5 880	25 979 068.57	0.63271 48646	595.12526	999	
	South	2 000 000	12.8102 73201	2 099 566.813	6.59319 50618	51.13276	1.02
Kansas	15.2	5 910	27 351 521.50	0.61452 81068	594.94263	999	
	North	2 000 000	12.5602 72222	2 099 621.745	6.68900 50779	50.13644	1.04
Kentucky	16.1	5 055	26 724 051.82	0.62206 72671	595.01754	999	
	South	2 000 000	13.0825 08590	2 099 586.678	6.49148 93225	52.21782	1.00
Kentucky	16.2	5 145	27 832 235.64	0.60646 23718	594.86305	999	
	North	2 000 000	16.0153 41985	2 099 522.345	5.54785 31326	63.90452	0.81
Louisiana	17.1	5 550	34 079 629.33	0.52870 06734	594.15095	999	
	South	2 000 000	17.2758 29558	2 099 545.450	5.2141C 08548	68.92709	0.75
Louisiana	17.2	5 480	36 756 553.45	0.50001 26971	593.91292	999	
	Offshore	2 000 000	19.5723 41939	2 099 480.464	4.69199 30345	80.02091	1.51
Louisiana	17.3	5 480	41 576 762.39	0.45400 68519	593.56012	4.33	

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
		800 000	12.3783 21478	2 099 596.059	6.76022 71189	49.41137	1.05
Maryland	19.0	4 620	26 369 112.76	0.62763 41196	595.07374	999	
	Mainland	600 000	11.0076 57990	2 099 626.929	7.34005 64125	43.94857	1.19
Massachusetts	20.1	4 290	23 549 477.32	0.67172 86561	595.53621	999	
	Island	200 000	11.3276 65409	2 099 698.180	7.19751 84389	45.22407	1.15
Massachusetts	20.2	4 230	23 924 398.02	0.66109 53994	595.42209	999	
	North	2 000 000	9.5455 94618	2 099 577.552	8.03286 43674	38.68398	7.89
Michigan	21.6	5 220	20 389 420.09	0.72278 99981	596.11375	6.20	
	Central	2 000 000	10.0027 30252	2 099 598.279	7.81862 74014	40.56489	6.61
Michigan	21.7	5 060	21 594 768.40	0.70640 74180	595.92424	6.08	
	South	2 000 000	10.7472 84488	2 099 586.043	7.45945 18656	43.62769	4.95
Michigan	21.8	5 060	23 069 597.22	0.68052 92633	595.63317	6.00	
	North	2 000 000	9.0423 16733	2 099 497.306	8.32350 57512	36.11389	1.45
Minnesota	22.1	5 586	19 471 398.75	0.74121 96637	596.33159	999	
	Central	2 000 000	9.5290 88412	2 099 537.632	8.06152 53999	38.05459	1.37
Minnesota	22.2	5 655	20 493 457.15	0.72338 80702	596.12002	999	
	South	2 000 000	10.1579 53472	2 099 537.679	7.74151 09282	40.56153	1.29
Minnesota	22.3	5 640	21 874 349.14	0.70092 77826	595.86162	999	
	North	2 000 000	8.9012 80761	2 099 641.490	8.40183 14127	35.55153	1.47
Montana	25.1	6 570	19 157 874.26	0.74645 18080	596.39431	999	
	Central	2 000 000	9.2558 18806	2 099 537.617	8.20702 13948	36.96514	1.41
Montana	25.2	6 570	19 919 806.36	0.73335 38278	596.23754	999	
	South	2 000 000	9.7644 74280	2 099 514.006	7.93936 49928	38.99298	1.34
Montana	25.3	6 570	21 096 820.93	0.71490 12442	596.02133	999	

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
	North	2 000 000	10.9563 97056	2 099 626.928	7.36331 64959	43.74423	1.19
Nebraska	26.1	6 000	23 368 977.46	0.63735 07906	595.55498	999	
	South	2 000 000	11.4808 89640	2 099 537.738	7.13086 65818	45.83467	1.14
Nebraska	26.2	5 970	24 590 781.86	0.65607 64003	595.36895	999	
	Long Island	2 000 000	11.5421 76825	2 099 690.654	7.10449 08273	46.07893	1.13
New York	31.4	4 440	24 462 545.30	0.65408 20950	595.34864	999	
		2 000 000	14.1166 91879	2 099 433.757	6.12860 74841	56.33878	0.92
North Carolina	32.0	4 740	30.183 611.25	0.57717 07700	594.58393	999	
	North	2 000 000	8.9636 82598	2 099 566.651	8.36703 98661	35.80031	1.46
North Dakota	33.1	6 030	19 215 516.01	0.74413 33961	596.36765	999	
	South	2 000 000	9.3643 26488	2 099 566.671	8.14877 03843	37.39771	1.40
North Dakota	33.2	6 030	20 086 977.18	0.72938 26040	596.19052	999	
	North	2 000 000	11.4541 06100	2 099 573.576	7.14244 39257	45.72791	1.14
Ohio	34.1	4 950	24 559 158.47	0.65695 03193	595.37833	999	
	South	2 000 000	12.1562 57795	2 099 566.844	6.84889 67952	48.52639	1.07
Ohio	34.2	4 950	26 027 071.12	0.63451 95439	595.14400	999	
	North	2 000 000	13.6492 91606	2 099 586.740	6.28815 79862	54.47632	0.95
Oklahoma	35.1	5 880	29 082 831.70	0.59014 70744	594.70553	999	
	South	2 000 000	14.4709 99525	2 099 566.862	6.01229 51464	57.75084	0.90
Oklahoma	35.2	5 880	30 838 032.96	0.56761 66827	594.49510	999	
	North	2 000 000	9.9244 81684	2 099 480.014	7.85796 14005	39.63095	1.32
Oregon	36.1	7 230	21 383 852.48	0.70918 60222	595.95556	999	
	South	2 000 000	10.6413 53445	2 099 480.066	7.50892 71822	42.48847	1.23
Oregon	36.2	7 230	22 888 667.15	0.68414 73833	595.67384	999	

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
	North	2 000 000	11.3141 69244	2 099 610.741	7.20343 82515	45.15854	1.15
Pennsylvania	37.1	4 665	24 211 050.37	0.66153 97363	595.42678	999	
	South	2 000 000	11.7058 53283	2 099 616.327	7.03483 46103	46.73136	1.11
Pennsylvania	37.2	4 665	24 984 826.43	0.64879 31663	595.29239	999	
	North	2 000 000	14.5886 44817	2 099 586.762	5.97452 58161	58.21947	0.89
South Carolina	39.1	4 860	31 127 724.75	0.56449 73800	594.46706	999	
	South	2 000 000	15.3613 74673	2 099 559.902	5.73648 89600	61.74753	0.84
South Carolina	39.2	4 860	32 676 887.64	0.54465 15700	594.28950	999	
	North	2 000 000	9.9652 16243	2 099 573.515	7.83744 62836	39.79320	1.31
South Dakota	40.1	6 000	21 366 697.03	0.70773 81841	595.93990	999	
	South	2 000 000	10.4755 96174	2 099 505.865	7.58740 89499	41.82781	1.25
South Dakota	40.2	6 020	22 461 937.05	0.68985 19579	595.73842	999	
		2 000 000	13.8170 73482	2 099 593.024	6.23006 34541	55.14496	0.94
Tennessee	41.0	5 160	29 535 149.91	0.58543 97296	594.66031	999	
	North	2 000 000	14.0303 44192	2 099 514.231	6.15754 99858	55.99482	0.93
Texas	42.1	6 090	29 972 959.94	0.57953 58654	594.60575	999	
	N.Central	2 000 000	15.3316 61298	2 099 433.907	5.74533 06210	61.18035	0.85
Texas	42.2	5 850	32 691 654.54	0.54539 44146	594.29572	999	
	Central	2 000 000	16.6003 72791	2 099 453.060	5.38829 78793	66.23589	0.78
Texas	42.3	6 020	35 337 121.23	0.51505 88857	594.03580	999	
	S.Central	2 000 000	17.7485 26687	2 099 414.214	5.09816.44664	70.81092	0.73
Texas	42.4	5 940	37 807 440.38	0.48991 26408	593.83362	999	
	South	2 000 000	19.5723 41939	2 099 480.464	4.69199 30345	78.07853	0.66
Texas	42.5	5 910	41 576 762.39	0.45400 68519	593.56012	999	

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
	North	2 000 000	11.3806 20205	2 099 610.744	7.17436 79884	45.43514	1.15
Utah	43.1	6 690	24 229 110.29	0.65935 54910	595.40334	999	
	Central	2 000 000	11.9634 71949	2 099 488.916	6.92746 87843	47.75829	1.09
Utah	43.2	6 690	25 664 114.42	0.64057 85926	595.20647	999	
	South	2 000 000	12.8719 59904	2 099 599.094	6.56991 23007	51.37860	1.01
Utah	43.3	6 690	27 432 812.88	0.61268 73424	594.92390	999	
	North	2 000 000	12.4929 92805	2 099 592.988	6.71519 24430	49.86859	1.04
Virginia	45.1	4 710	26 576 444.45	0.62411 78597	595.03784	999	
	South	2 000 000	13.0667 62019	2 099 586.724	6.49729 89409	52.15482	1.00
Virginia	45.2	4 710	27 811 312.71	0.60692 48249	594.86773	999	
	North	2 000 000	8.9532 57623	2 099 580.115	8.37283 68522	35.75876	1.46
Washington	46.1	7 250	19 205 863.43	0.74452 03390	596.37236	999	
	South	2 000 000	9.4462 70779	2 099 522.021	8.01519 85672	37.72440	1.39
Washington	46.2	7 230	20 289 119.60	0.72639 57947	596.15605	999	
	North	2 000 000	12.6524 41881	2 099 576.946	6.89102 19040	48.11250	1.08
West Virginia	47.1	4 770	25 715 126.55	0.63777 29696	595.17836	999	
	South	2 000 000	12.6881 39167	2 099 545.339	6.63970 86618	50,64632	1.03
West Virginia	47.2	4 860	27 070 620.78	0.61819 53936	594.97852	999	
	North	2 000 000	9.5848 07314	2 099 586.605	8.03234 65428	38.27671	1.36
Wisconsin	48.1	5 400	20 489 179.67	0.72137 07913	596.09808	999	
	Central	2 000 000	10.0261 85452	2 099 576.862	7.80689 71899	40.03631	1.30
Wisconsin	48.2	5 400	21 430 913.91	0.70557 66312	595.91485	999	
	South	2 000 000	10.5552 75906	2 099 559,732	7.54951 94619	42.14537	1.24
Wisconsin	48.3	5 400	22 672 134.66	0.68710 32423	595.70670	999	

APPENDIX G

TRANSFORMATION OF STATE PLANE COORDINATES (LAMBERT PROJECTION) TO GEODETIC COORDINATES (NORTH AMERICAN DATUM 1927)

Purpose: Reference TM 5-237, Surveying Computer's Manual, 1964 Page 366, Paragraphs 179/188.

The Lambert Conical Conformal type of projection is used with one or two standard parallels in areas extending mainly in an east-west direction. The projection provides very simple formulas for the conversion of grid to geodetic coordinates using the included constants. This projection is used for many states by the National Geodetic Survey (NGS) for the state plane grid systems in the United States.

NOTES:

1. This program is designed to be used with the TI Printer (PC-188 Series).
2. The listed program is written using the constants necessary to convert state plane coordinates (Lambert Projection, California, Zone V) to geodetic coordinates (North American Datum 1927).
3. The program listing/instructions can be modified for storage on magnetic cards for specific states or the constants can be input after initializing and depressing "E". See the attached listing of state/zone constants and codes.

INSTRUCTIONS:

1. Printer "ON" and, then, Calculator "ON".

2. Load the three sides of the magnetic cards:

   a. CLR, RST, 2, 2nd, OP, 17, 1, 2nd, WRITE; Enter Side 1.

   b. 2; Enter Side 2.

   c. 3; Enter Side 3.

Note: The numbers which are underlined may be replaced by zeroes. Refer to operating insturction manual if difficulty occurs.

3. Depress "A" for initialization and:

   a. State, Zone, Grid/Geod.

   b. Constants, Storage Registers.

   c. Instructions for input of new constants and/or coordinates.

4. Output includes the latitude and longitude values and the mapping angle (or convergence angle) for use with known azimuths at the station.

INPUT DATA:

1. New Constants, L1 through L11 (see attached listings).

2. Grid coordinate "x", in feet.

3. Grid coordinate "y", in feet.

FORMULATION and COMPUTATION:

1. Computations are performed in radians.

2. The equations used are from C & GS Publication 62-4 as modified by T. Vincenty for use in small calculators.

$$\theta = \arctan (x - x_o)/(R_1 - y)$$

$$\lambda = \lambda_o - (\theta/(\sin \phi_o))$$

$$R = (R_1 - y)/\cos \theta$$

$$\beta = (R_1 - R_o - y + 2R \sin^2 (\theta/2))/cm$$

$$\sigma = \beta(1 + E \beta^2 (F\beta (1 + H\beta) - 1))$$

Where: E, F, and H are from C & GS Pub 62-4 values of L_9, L_{10}, abd L_{11} as follows:

$$E = L_9 c^2 10^{-16} \quad F = L_{10} c10^{-8}/L_9$$

$$H = L_9 (3 L_9^2 - L_{11}) c 10^{-8}/L_{10}$$

$$\omega = \omega_0 - 1.005104574 \sigma$$

$$\phi = \omega + B' \sin \omega \cos \omega (1 + C' \cos^2 \omega (1 + D' \cos^2 \omega))$$

Where: $1/B' = 196.90273$
$1/C' = 169.1567$
$1/D' = 121.64$

SAMPLE RUNS

```
CA 4.5 LAM GRID/GEOD

     2000000.        09
        7080.        10
 14.38132943        11
 30649424.27        12
 2099537.853        13
 .5700119219        14
 6.041365233        15
   594.51692        16
    57.39339        17
        999.        18
        0.91        19

E:NEW CONSTANTS   OR

INPUT X IN FEET, THEN
      Y IN FEET



    2300000.
     545000.

LATITUDE
          34.      DEG
          59.      MIN
    36.53660       SEC

LONGITUDE
         116.      DEG
          59.      MIN
    54.06612       SEC

MAP ANGLE
           0.      DEG
          34.      MIN
    15.42525       SEC

ANOTHER?

INPUT X IN FEET, THEN
      Y IN FEET
```

```
000  98 ADV
001  98 ADV
002  02  2
003  52 EE
004  06  6
005  22 INV
006  52 EE
007  42 STO
008  09  09
009  07  7
010  00  0
011  08  8
012  00  0
013  42 STO
014  10  10
015  01  1
016  04  4
017  93  .
018  03  3
019  08  8
020  01  1
021  03  3
022  02  2
023  09  9
024  04  4
025  03  3
026  09  9
027  42 STO
028  11  11
029  03  3
030  00  0
031  06  6
032  04  4
033  09  9
034  04  4
035  02  2
036  04  4
037  93  .
038  02  2
039  07  7
040  42 STO
041  12  12
042  02  2
043  00  0
044  09  9
045  09  9
046  05  5
047  03  3
048  07  7
049  93  .
050  08  8
051  05  5
052  03  3
053  42 STO
054  13  13
055  93  .
056  05  5
057  07  7
058  00  0
059  00  0
060  01  1
061  01  1
062  09  9
063  02  2
064  01  1
065  09  9
066  42 STO
067  14  14
068  06  6
069  93  .
070  00  0
071  04  4
072  01  1
073  03  3
074  06  6
075  05  5
076  02  2
077  03  3
078  03  3
079  08  8
080  09  9
081  42 STO
082  15  15
083  05  5
084  09  9
085  04  4
086  93  .
087  05  5
088  01  1
089  06  6
090  09  9
091  02  2
092  42 STO
093  16  16
094  05  5
095  07  7
096  93  .
097  03  3
098  09  9
099  03  3
100  03  3
101  09  9
102  42 STO
103  17  17
104  09  9
105  09  9
106  09  9
107  42 STO
108  18  18
109  93  .
110  09  9
111  01  1
112  42 STO
113  19  19
114  22 INV
115  58 FIX
116  69 OP
117  00  00
118  01  1
119  05  5
120  01  1
121  03  3
122  00  0
123  00  0
124  00  0
125  05  5
126  04  4
127  00  0
128  69 OP
129  01  01
130  00  0
131  06  6
132  00  0
133  00  0
134  02  2
135  07  7
136  01  1
137  03  3
138  03  3
139  00  0
140  69 OP
141  02  02
142  02  2
143  02  2
144  03  3
145  05  5
146  02  2
147  04  4
148  01  1
149  06  6
150  69 OP
151  03  03
152  06  6
153  03  3
154  02  2
155  02  2
156  01  1
157  07  7
158  03  3
159  02  2
160  01  1
161  06  6
162  69 OP
163  04  04
164  69 OP
165  05  05
166  98 ADV
167  09  9
168  22 INV
169  90 LST
170  98 ADV
171  01  1
172  07  7
173  06  6
174  02  2
175  03  3
176  01  1
177  01  1
178  07  7
179  04  4
180  03  3
181  69 OP
182  01  01
183  01  1
184  05  5
185  03  3
186  02  2
187  03  3
188  01  1
189  03  3
190  06  6
191  69 OP
192  02  02
193  03  3
194  07  7
195  01  1
196  03  3
197  03  3
198  01  1
199  03  3
```

200	07	7	250	07	7	300	42	STO	350	43	RCL
201	03	3	251	02	2	301	03	03	351	19	19
202	06	6	252	03	3	302	42	STO	352	85	+
203	69	OP	253	01	1	303	04	04	353	01	1
204	03	03	254	07	7	304	35	1/X	354	95	=
205	03	3	255	03	3	305	65	×	355	16	A'
206	02	2	256	01	1	306	53	(	356	19	D'
207	03	3	257	69	OP	307	18	C'	357	55	÷
208	05	5	258	04	04	308	75	-	358	43	RCL
209	69	OP	259	98	ADV	309	43	RCL	359	17	17
210	04	04	260	69	OP	310	09	09	360	75	-
211	69	OP	261	05	05	311	54	)	361	01	1
212	05	05	262	69	OP	312	95	=	362	95	=
213	76	LBL	263	00	00	313	22	INV	363	16	A'
214	38	SIN	264	04	4	314	30	TAN	364	33	X^2
215	02	2	265	05	5	315	42	STO	365	19	D'
216	04	4	266	00	0	316	02	02	366	19	D'
217	03	3	267	00	0	317	39	COS	367	55	÷
218	01	1	268	02	2	318	22	INV	368	43	RCL
219	03	3	269	04	4	319	49	PRD	369	16	16
220	03	3	270	03	3	320	03	03	370	85	+
221	04	4	271	01	1	321	18	C'	371	01	1
222	01	1	272	69	OP	322	55	÷	372	95	=
223	03	3	273	02	02	323	02	2	373	16	A'
224	07	7	274	02	2	324	95	=	374	95	=
225	69	OP	275	01	1	325	38	SIN	375	65	×
226	01	01	276	01	1	326	33	X^2	376	01	1
227	04	4	277	07	7	327	16	A'	377	93	.
228	04	4	278	01	1	328	65	×	378	00	0
229	00	0	279	07	7	329	02	2	379	00	0
230	00	0	280	03	3	330	75	-	380	05	5
231	02	2	281	07	7	331	43	RCL	381	01	1
232	04	4	282	69	OP	332	11	11	382	00	0
233	03	3	283	03	03	333	65	×	383	04	4
234	01	1	284	69	OP	334	43	RCL	384	05	5
235	69	OP	285	05	05	335	13	13	385	07	7
236	02	02	286	98	ADV	336	85	+	386	04	4
237	02	2	287	98	ADV	337	43	RCL	387	94	+/-
238	01	1	288	98	ADV	338	04	04	388	85	+
239	01	1	289	25	CLR	339	95	=	389	43	RCL
240	07	7	290	91	R/S	340	55	+	390	15	15
241	01	1	291	99	PRT	341	43	RCL	391	19	D'
242	07	7	292	42	STO	342	13	13	392	35	1/X
243	03	3	293	02	02	343	19	D'	393	95	=
244	07	7	294	43	RCL	344	35	1/X	394	42	STO
245	69	OP	295	12	12	345	95	=	395	03	03
246	03	03	296	75	-	346	42	STO	396	39	COS
247	05	5	297	91	R/S	347	03	03	397	33	X^2
248	07	7	298	99	PRT	348	19	D'	398	55	+
249	03	3	299	95	=	349	55	+	399	01	1

400	02	2	450	03	3	500	02	2	550	02	02
401	01	1	451	07	7	501	02	2	551	69	DP
402	93	.	452	02	2	502	02	2	552	05	05
403	06	6	453	04	4	503	04	4	553	17	B'
404	04	4	454	03	3	504	69	DP	554	98	ADV
405	85	+	455	07	7	505	01	01	555	69	DP
406	01	1	456	69	DP	506	03	3	556	00	00
407	95	=	457	01	01	507	07	7	557	01	1
408	16	A'	458	04	4	508	04	4	558	03	3
409	39	COS	459	01	1	509	01	1	559	03	3
410	33	X^2	460	01	1	510	01	1	560	01	1
411	55	÷	461	06	6	511	06	6	561	03	3
412	01	1	462	01	1	512	01	1	562	02	2
413	06	6	463	07	7	513	07	7	563	03	3
414	09	9	464	00	0	514	00	0	564	07	7
415	93	.	465	00	0	515	00	0	565	02	2
416	01	1	466	00	0	516	69	DP	566	03	3
417	05	5	467	00	0	517	02	02	567	69	DP
418	06	6	468	69	DP	518	69	DP	568	01	01
419	07	7	469	02	02	519	05	05	569	01	1
420	85	+	470	69	DP	520	17	B'	570	07	7
421	01	1	471	05	05	521	18	C'	571	03	3
422	95	=	472	17	B'	522	98	ADV	572	05	5
423	16	A'	473	43	RCL	523	42	STO	573	07	7
424	39	COS	474	10	10	524	05	05	574	01	1
425	16	A'	475	65	×	525	69	DP	575	00	0
426	38	SIN	476	89	π	526	00	00	576	00	0
427	55	÷	477	55	÷	527	03	3	577	00	0
428	01	1	478	01	1	528	00	0	578	00	0
429	09	9	479	00	0	529	01	1	579	69	DP
430	06	6	[illegible]	08	8	530	03	3	580	02	02
431	93	.	481	00	0	531	03	3	581	69	DP
432	09	9	482	00	0	532	03	3	582	05	05
433	00	0	483	75	-	533	00	0	583	61	GTO
434	02	2	484	18	C'	534	00	0	584	38	SIN
435	07	7	485	55	÷	535	01	1	585	76	LBL
436	03	3	486	43	RCL	536	03	3	586	16	A'
437	85	+	487	14	14	537	69	DP	587	65	×
438	01	1	488	95	=	538	01	01	588	43	RCL
439	16	A'	489	98	ADV	539	03	3	589	03	03
440	95	=	490	42	STO	540	01	1	590	92	RTN
441	98	ADV	491	05	05	541	02	2	591	76	LBL
442	42	STO	492	69	DP	542	02	2	592	18	C'
443	05	05	493	00	00	543	02	2	593	43	RCL
444	69	DP	494	02	2	544	07	7	594	02	02
445	00	00	495	07	7	545	01	1	595	92	RTN
446	02	2	496	03	3	546	07	7	596	76	LBL
447	07	7	497	02	2	547	00	0	597	19	D'
448	01	1	498	03	3	548	00	0	598	65	×
449	03	3	499	01	1	549	69	DP	599	01	1

600	00	0	650	01	1	700	01	1	750	55	÷
601	92	RTN	651	06	6	701	00	0	751	43	RCL
602	76	LBL	652	01	1	702	00	0	752	01	01
603	15	E	653	07	7	703	95	=	753	75	-
604	99	PRT	654	02	2	704	58	FIX	754	01	1
605	98	ADV	655	02	2	705	05	05	755	02	2
606	09	9	656	69	DP	706	69	DP	756	65	×
607	42	STO	657	04	04	707	06	06	757	43	RCL
608	00	00	658	43	RCL	708	22	INV	758	06	06
609	01	1	659	05	05	709	58	FIX	759	54	)
610	01	1	660	59	INT	710	92	RTN	760	95	=
611	42	STO	661	22	INV	711	76	LBL	761	44	SUM
612	01	01	662	44	SUM	712	11	A	762	08	08
613	76	LBL	663	05	05	713	70	RAD	763	61	GTO
614	33	X^2	664	69	DP	714	22	INV	764	88	DMS
615	43	RCL	665	06	06	715	58	FIX	765	76	LBL
616	00	00	666	03	3	716	81	RST	766	17	B'
617	98	ADV	667	00	0	717	00	0	767	03	3
618	99	PRT	668	02	2	718	00	0	768	00	0
619	75	-	669	04	4	719	00	0	769	03	3
620	08	8	670	03	3	720	25	CLR	770	07	7
621	95	=	671	01	1	721	70	RAD	771	03	3
622	91	R/S	672	69	DP	722	98	ADV	772	05	5
623	99	PRT	673	04	04	723	81	RST	773	03	3
624	72	ST*	674	43	RCL	724	76	LBL	774	06	6
625	00	00	675	05	05	725	19	D'	775	69	DP
626	69	DP	676	65	×	726	88	DMS	776	04	04
627	20	20	677	01	1	727	65	×	777	92	RTN
628	00	0	678	00	0	728	89	π	778	76	LBL
629	97	DSZ	679	00	0	729	55	÷	779	18	C'
630	01	01	680	95	=	730	01	1	780	58	FIX
631	33	X^2	681	42	STO	731	08	8	781	03	03
632	61	GTO	682	05	05	732	00	0	782	69	DP
633	38	SIN	683	59	INT	733	54	)	783	06	06
634	92	RTN	684	22	INV	734	92	RTN	784	98	ADV
635	76	LBL	685	44	SUM	735	76	LBL	785	22	INV
636	17	B'	686	05	05	736	16	A'	786	58	FIX
637	43	RCL	687	69	DP	737	43	RCL	787	69	DP
638	05	05	688	06	06	738	08	08	788	00	00
639	65	×	689	03	3	739	55	÷	789	92	RTN
640	01	1	690	06	6	740	43	RCL	790	00	0
641	08	8	691	01	1	741	01	01	791	00	0
642	00	0	692	07	7	742	55	÷	792	00	0
643	55	÷	693	01	1	743	02	2	793	00	0
644	89	π	694	05	5	744	04	4	794	00	0
645	95	=	695	69	DP	745	65	×	795	00	0
646	22	INV	696	04	04	746	53	(	796	00	0
647	88	DMS	697	43	RCL	747	43	RCL	797	00	0
648	42	STO	698	05	05	748	08	08	798	00	0
649	05	05	699	65	×	749	33	X^2	799	00	0

AD-A118 854 ARMY WAR COLL CARLISLE BARRACKS PA F/G 9/2
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APPENDIX

Lambert Projection Constants

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
	10	3 000 000	7.5707 74528	2 099 382.342	9.19729 71118	50.58736	-106
Alaska*	50.0	10 560	16 564 628.77	0.79692 23940	397.02694	6.40	
	North	2 000 000	13.9445 87488	2 099 566.849	6.18653 07455	55.65314	0.93
Arkansas	3.1	5 520	29 732 882.87	0.58189 91407	594.62757	999	
	South	2 000 000	14.7718 94984	2 099 530.173	5.91651 81558	58.94981	0.88
Arkansas	3.2	5 520	31 511 724.20	0.55969 06871	594.47485	999	
	I	2 000 000	11.5482 67459	2 099 480.129	7.10187 84606	46.10317	1.13
California	4.1	7 320	24 792 436.23	0.65388 43192	595.34551	999	
	II	2 000 000	12.2865 33640	2 099 522.214	6.79664 27326	49.04553	1.06
California	4.2	7 320	26 312 257.65	0.63046 79732	595.10340	999	
	III	2 000 000	12.8872 57544	2 099 552.659	6.56416 00543	51.43955	1.01
California	4.3	7 230	27 512 992.04	0.61223 20427	594.91922	999	
	IV	2 000 000	13.4228 96887	2 099 576.982	6.36804 49092	53.57406	0.97
California	4.4	7 140	28 652 931.96	0.59658 71443	594.76790	999	
	V	2 000 000	14.3813 29439	2 099 537.853	6.04136 52389	57.39339	0.91
California	4.5	7 080	30 649 424.27	0.57001 19219	594.51692	999	
	VI	2 000 000	15.1678 86218	2 099 605.078	5.79450 10359	60.52780	0.86
California	4.6	6 975	32 271 267.72	0.54951 75982	594.33154	999	
	VII	4 186 692.58	14.7124 42842	2 099 677.289	5.93522 87569	58.71246	0.88
California	4.7	7 100	35 055 396.31	0.56124 32071	594.44057	999	
	North	2 000 000	11.7888 03056	2 099 610.755	6.99996 40610	47.06188	1.11
Colorado	5.1	6 330	25 086 068.20	0.64613 34829	595.26427	999	
	Central	2 000 000	12.2793 79233	2 099 566.796	6.79949 49875	49.01733	1.06
Colorado	5.2	6 330	26 243 052.74	0.63068 95773	595.10497	999	

* In eastern hemisphere use L2 = -11040 and enter longitude as negative east of Greenwich.

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
	South	2 000 000	12.8487 82891	2 099 586.717	6.57864 36904	51.28621	1.01
Colorado	5.3	6 330	27 402 231.82	0.61337 80528	594.93171	999	
		600 000	11.2680 94062	2 099 665.962	8.27090 58758	44.98648	1.16
Connecticut	6.0	4 365	23 914 389.02	0.66305 94147	595.44397	999	
	North	2 000 000	17.1606 79006	2 099 593.089	5.24307 17084	68.46860	0.76
Florida	9.3	5 070	36 454 924.53	0.50252 59000	593.93314	999	
	North	2 000 000	10.8292 50755	2 099 586.652	7.42152 89284	43.23744	1.21
Iowa	14.1	5 610	23 162 461.59	0.67774 45518	595.60346	999	
	South	2 000 000	11.4005 83645	2 099 592.955	7.16567 22121	45.51460	1.15
Iowa	14.2	5 610	24 374 096.67	0.65870 10213	595.39708	999	
	North	2 000 000	12.2141 49149	2 099 610.772	6.82539 35033	48.74582	1.07
Kansas	15.1	5 880	25 979 068.57	0.63271 48646	595.12526	999	
	South	2 000 000	12.8102 73201	2 099 566.813	6.59319 50618	51.13276	1.02
Kansas	15.2	5 910	27 351 521.50	0.61452 81068	594.94263	999	
	North	2 000 000	12.5602 72222	2 099 621.745	6.68900 50779	50.13644	1.04
Kentucky	16.1	5 055	26 724 051.82	0.62206 72671	595.01754	999	
	South	2 000 000	13.0825 08590	2 099 586.678	6.49148 93225	52.21762	1.00
Kentucky	16.2	5 145	27 832 235.64	0.60646 23718	594.86305	999	
	North	2 000 000	16.0153 41985	2 099 522.345	5.54785 31326	63.90452	0.81
Louisiana	17.1	5 550	34 079 629.33	0.52870 06734	594.15095	999	
	South	2 000 000	17.2758 29558	2 099 543.450	5.21410 08548	68.92709	0.75
Louisiana	17.2	5 480	36 756 553.45	0.50001 26971	593.91292	999	
	Offshore	2 000 000	19.5723 41939	2 099 480.464	4.69199 30345	80.02091	1.51
Louisiana	17.3	5 480	41 576 762.39	0.45400 68519	593.56012	4.33	

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
		800 000	12.3783 21478	2 099 596.059	6.76022 71189	49.41137	1.05
Maryland	19.0	4 620	26 369 112.76	0.62763 41196	595.07374	999	
	Mainland	600 000	11.0076 57990	2 099 626.929	7.34005 64125	43.94857	1.19
Massachusetts	20.1	4 290	23 549 477.32	0.67172 86561	595.53621	999	
	Island	200 000	11.3276 65409	2 099 698.180	7.19751 84389	45.22407	1.15
Massachusetts	20.2	4 230	23 924 398.02	0.66109 53994	595.42209	999	
	North	2 000 000	9.5455 94618	2 099 577.552	8.05286 43674	38.68598	7.89
Michigan	21.6	5 220	20 589 420.09	0.72278 99981	596.11375	6.20	
	Central	2 000 000	10.0027 30252	2 099 598.279	7.81862 74014	40.56489	6.61
Michigan	21.7	5 060	21 594 768.40	0.70640 74180	595.98426	6.08	
	South	2 000 000	10.7472 84488	2 099 586.043	7.45945 18856	43.62769	4.95
Michigan	21.8	5 060	23 069 597.22	0.68052 92633	595.63317	6.00	
	North	2 000 000	9.0423 16733	2 099 497.306	8.32350 57512	36.11389	1.45
Minnesota	22.1	5 586	19 471 398.75	0.74121 96637	596.33159	999	
	Central	2 000 000	9.5290 88412	2 099 537.632	8.06152 53999	38.05459	1.37
Minnesota	22.2	5 655	20 493 457.15	0.72338 80702	596.12002	999	
	South	2 000 000	10.1579 53472	2 099 537.679	7.74151 09282	40.56153	1.29
Minnesota	22.3	5 640	21 874 349.14	0.70092 77824	595.86162	999	
	North	2 000 000	8.9012 80761	2 099 641.490	8.40183 14127	35.55153	1.47
Montana	25.1	6 570	19 157 874.26	0.74645 18080	596.39431	999	
	Central	2 000 000	9.2558 18806	2 099 537.617	8.20702 13948	36.96514	1.41
Montana	25.2	6 570	19 919 806.36	0.73335 38278	596.23754	999	
	South	2 000 000	9.7644 74280	2 099 514.006	7.93936 49928	38.99298	1.34
Montana	25.3	6 570	21 096 820.93	0.71490 12442	596.02133	999	

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
	North	2 000 000	10.9563 97056	2 099 626.928	7.36331 64959	43.74423	1.19
Nebraska	26.1	6 000	23 368 977.46	0.63735 07906	595.55498	999	
	South	2 000 000	11.4808 89640	2 099 537.738	7.13086 65818	45.83467	1.14
Nebraska	26.2	5 970	24 590 781.86	0.65607 64003	595.36895	999	
	Long Island	2 000 000	11.5421 76825	2 099 690.654	7.10449 08273	46.07893	1.13
New York	31.4	4 440	24 462 545.30	0.65408 20950	595.34864	999	
		2 000 000	14.1166 91879	2 099 433.757	6.12860 74841	56.33878	0.92
North Caroling	32.0	4 740	30.183 611.25	0.57717 07700	594.58393	999	
	North	2 000 000	8.9636 82598	2 099 566.651	8.36703 98661	35.80031	1.46
North Dakota	33.1	6 030	19 215 516.01	0.74413 33961	596.36765	999	
	South	2 000 000	9.3643 26488	2 099 566.671	8.14877 03843	37.39771	1.40
North Dakota	33.2	6 030	20 086 977.18	0.72938 26040	596.19052	999	
	North	2 000 000	11.4541 06100	2 099 573.576	7.14244 39257	45.72791	1.14
Ohio	34.1	4 950	24 559 158.47	0.65695 03193	595.37833	999	
	South	2 000 000	12.1562 57795	2 099 566,844	6.84889 67952	48.52639	1.07
Ohio	34.2	4 950	26 027 071.12	0.63451 95439	595.14400	999	
	North	2 000 000	13.6492 91606	2 099 586,740	6.28815 79862	54.47632	0.95
Oklahoma	35.1	5 880	29 082 831.70	0.59014 70744	594.70553	999	
	South	2 000 000	14.4709 99525	2 099 566.862	6.01229 51464	57.75084	0.90
Oklahoma	35.2	5 880	30 838 032.96	0.56761 66827	594.49510	999	
	North	2 000 000	9.9244 81684	2 099 480.014	7.85796 14005	39.63095	1.32
Oregon	36.1	7 230	21 383 852.48	0.70918 60222	595.95556	999	
	South	2 000 000	10.6413 53445	2 099 480,066	7.50892 71822	42.48847	1.23
Oregon	36.2	7 230	22 888 667.15	0.68414 73833	595.67384	999	

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
	North	2 000 000	11.3141 69244	2 099 610.741	7.20343 82515	45.15854	1.15
Pennsylvania	37.1	4 665	24 211 050.37	0.66153 97363	595.42678	999	
	South	2 000 000	11.7058 53283	2 099 616.327	7.03483 46103	46.73136	1.11
Pennsylvania	37.2	4 665	24 984 826.43	0.64879 31663	595.29239	999	
	North	2 000 000	14.5886 44817	2 099 586.782	5.97452 58161	58.21947	0.89
South Carolina	39.1	4 860	31 127 724.75	0.56449 73800	594.46706	999	
	South	2 000 000	15.3613 74673	2 099 559.902	5.73648 89600	61.74753	0.84
South Carolina	39.2	4 860	32 676 887.64	0.54465 15700	594.28990	999	
	North	2 000 000	9.9652 16243	2 099 573.515	7.83744 62836	39.79320	1.31
South Dakota	40.1	6 000	21 366 697.03	0.70773 81841	595.93990	999	
	South	2 000 000	10.4755 96174	2 099 505.865	7.58740 89499	41.82781	1.25
South Dakota	40.2	6 020	22 461 937.05	0.68985 19579	595.73842	999	
		2 000 000	13.8170 73482	2 099 593.024	6.23006 34541	55.14496	0.94
Tennessee	41.0	5 160	29 535 149.91	0.58543 97296	594.66031	999	
	North	2 000 000	14.0303 44192	2 099 514.231	6.15754 99858	55.99482	0.93
Texas	42.1	6 090	29 972 959.94	0.57933 58654	594.60575	999	
	N.Central	2 000 000	15.3316 61298	2 099 433.907	5.74533 06210	61.18035	0.85
Texas	42.2	5 850	32 691 654.54	0.54539 44146	594.29572	999	
	Central	2 000 000	16.6003 72791	2 099 453.060	5.38829 78793	66.23589	0.78
Texas	42.3	6 020	35 337 121.23	0.51505 88857	594.03580	999	
	S.Central	2 000 000	17.7485 26687	2 099 414.214	5.09816.44664	70.81092	0.73
Texas	42.4	5 940	37 807 440.38	0.48991 26408	593.83362	999	
	South	2 000 000	19.5723 41939	2 099 480.464	4.69199 30345	78.07853	0.66
Texas	42.5	5 910	41 576 762.39	0.45400 68519	593.56012	999	

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
	North	2 000 000	11.3806 20205	2 099 610.744	7.17436 79884	45.43514	1.15
Utah	43.1	6 690	24 229 110.29	0.65935 54910	595.40334	999	
	Central	2 000 000	11.9634 71949	2 099 488.916	6.92746 87843	47.75829	1.09
Utah	43.2	6 690	25 664 114.42	0.64057 85926	595.20647	999	
	South	2 000 000	12.8719 59904	2 099 599.094	6.56991 23007	51.37860	1.01
Utah	43.3	6 690	27 432 812.88	0.61268 73424	594.92390	999	
	North	2 000 000	12.4929 92805	2 099 592.988	6.71519 24430	49.86859	1.04
Virginia	45.1	4 710	26 576 444.45	0.62411 78597	595.03784	999	
	South	2 000 000	13.0667 62019	2 099 586.724	6.49729 89409	52.15482	1.00
Virginia	45.2	4 710	27 811 312.71	0.60692 48249	594.86773	999	
	North	2 000 000	8.9532 57623	2 099 580.115	8.37283 68522	35.75876	1.46
Washington	46.1	7 250	19 205 863.43	0.74452 03390	596.37296	999	
	South	2 000 000	9.4462 70779	2 099 522.021	8.01519 85672	37.72440	1.39
Washington	46.2	7 230	20 289 119.60	0.72639 57947	596.15605	999	
	North	2 000 000	12.0524 41881	2 099 576.946	6.89102 19040	48.11250	1.08
West Virginia	47.1	4 770	25 715 126.55	0.63777 29696	595.17836	999	
	South	2 000 000	12.6881 39167	2 099 545.339	6.63970 86618	50.64632	1.03
West Virginia	47.2	4 860	27 070 620.78	0.61819 53936	594.97852	999	
	North	2 000 000	9.5848 07314	2 099 586.605	8.05234 65428	38.27671	1.36
Wisconsin	48.1	5 400	20 489 179.67	0.72137 07913	596.09808	999	
	Central	2 000 000	10.0261 85452	2 099 576.862	7.80689 71899	40.03631	1.30
Wisconsin	48.2	5 400	21 430 913.91	0.70557 66312	595.91485	999	
	South	2 000 000	10.5552 75906	2 099 559,732	7.54951 94619	42.14537	1.24
Wisconsin	48.3	5 400	22 672 134.66	0.68710 32423	595.70670	999	

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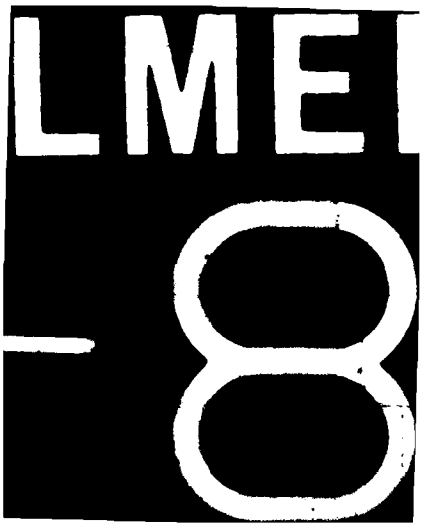
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